TRIPURA UNIVERSITY
DEPARTMENT OF MATHEMATICS
PROPOSED NEW MSc CURRICULUM-2015

CORE COURSES

Course Code	Name of the Courses	Credits
MATH 701C	Real Analysis	4
MATH 702C	Complex Analysis	3
MATH 703C	Ordinary Different Equations & Partial Different Equations	4
MATH 801C	Abstract Algebra	4
MATH 802C	Topology	4
MATH803C	Mathematical Methods	3
MATH 901C	Fuzzy Set Theory	3
MATH 902C	Functional Analysis	4
MATH 903C	Computer Programming(C and MATLAB)	2
MATH904C	Numerical Analysis	2
MATH 905C	Project-I	4
MATH 1001C	Lebesgue Measure and Integration	3
MATH 1002C	Numerical Practical through Computer Program (C and MATLAB)	4
MATH 1003C	Project-II	4

DEPARTMENTAL ELECTIVE COURSES

Course Code	Name of the Courses	Credits
MATH 704E	Linear Algebra	4
MATH 705E	Operation Research	4
MATH 706E	Logic	4
MATH 805E	Set Theory	4
MATH 806E	Discrete Mathematics	4
MATH 906E	Advanced Topology	4
MATH 907E	Differential Topology	4
MATH 908E	Rough Sets and Applications	4
MATH 1004E	Fuzzy Logic and Applications	4
MATH 1005E	Fuzzy Topology	4
MATH 1006E	Sequence Space, Summability Theory and its Applications	4
MATH 1007E	Riemannian Geometry	4
MATH 1008E	Algebraic Topology	4
MATH 1009E	Number Theory	4

Compulsory foundation courses

Course Code	Name of the Courses	Credits
MATH804FC	Computer Skills III	4

Elective foundation courses

Course Code	Name of the Courses	Credits
	Craft Work-Jute(Fine Arts Dept)/	2
	Craft Work-Bamboo(Fine Arts Dept)/	2
	Creative Painting(Fine Arts Dept)/	2
	Creative Sculpture(Fine Arts Dept)/	2
	Aesthetics of Music(Music Dept.)/	4
	Yoga(Physical Education Dept.)/	2
	Communicative English(English Dept.)/	2
	NSS/	2
	Social Services	2

A student has to earn minimum 68 credits for getting the Degree of MA/MSc in Mathematics. In one semester a student can earn maximum 20 credits. A student have to earn 48 Credits from core courses of the concerned Department, minimum 16 credits from elective papers in which minimum 4 credits is to be earned from other Department and 4 credits from compulsory Foundation Course. Elective Foundation can be taken by a student out of his/her own interest, which is not compulsory.

.

Semester-I	Credit	Semester-II	Credit
MATH701C-Real Analysis	4	MATH801C-Abstract Algebra	4
MATH702C-Complex Analysis	3	MATH802C-Topology	4
MATH703C-Ordinary Differential Equations & Partial Differential Equations	4	MATH803C- Mathematical Methods	3
		MATH804FC- Computer Skills III	4
Semester-III	**Credit**	**Semester-IV**	**Credit**
MATH901C- Fuzzy Set Theory	3	MATH1001C-Lebesgue Measure and Integration	3
MATH902C- Functional Analysis	4	MATH 1002C-Numerical Practical through Computer Programming(C and MATLAB)	4
MATH903C-Computer Programming(C and MATLAB)	2	MATH1003C-Project-II	4
MATH904C-Numerical Analysis	2		
MATH905C-Project-I	4		

MATH 701C
Real Analysis (Credit-4)

1. **Cardinality, Order** : Integer and rational, real numbers, dedakind section ,equivalent sets, Denumerable and countable sets, continuum, Schroeder – Bernstein theorem, cardinality, partially ordered set, subsets of ordered sets, first and last elements, maximal and minimal elements , upper and lower bounds, Zorn's lemma.
2. **Metric Space** : Definitions and examples, open sphere, closed sphere (elements of point set theory), sequences, Cauchy sequences, Cantor intersection theorem, complete metric space, continuity and compactness, Baire Category theorem , equivalent metric , extension theorem , uniform continuity.
3. **Functions of bounded variation** : Total variation , continuous function of bounded variation, function of bounded variation expressed as the difference of the increasing functions.
4. **Riemann – Stieltje's integral**: Definitions and examples , integration and differentiation , the upper and lower Darboux - Stieltje's integrals.
5. **Sequence and series of function**: Uniform convergence, Weierstrass's M- test, uniform convergence and continuity, term by term integration, term by term differentiation, power series, Weierstrass approximation theorem.
6. **Fourier series**: Expansion of periodic function, Sine series and Cosine series, change of interval, convergence theorem, Riemann – Lebesgue lemma, Bessel's inequality and Parseval's theorem.

References:

1. W. Rudin , Principle of Mathematical Analysis, Mc Grow Hill 1976.
2. T. M. Apostal , Mathematical Analysis , Narosa pub. House 1985.
3. M. H. Potter and C. B. Morrey , A first course in Real analysis, Springer.
4. D. Somasundaram & B. Choudhury , A first course in Mathematical analysis, Narosa pub. House 1999.

MATH 702C
Complex Analysis (Credit-3)

1. Structure of complex plane, continuity and differentiability of complex function. Analytic function.
2. Complex integration, Cauchy theorem, Cauchy-Goursat theorem. Cauchy integral formula, Cauchy integral formula for higher derivatives, Moreras theorem, Cauchy inequality, Liouville’s theorem, Fundamental theorem of Algebra.
3. Sequence and series of functions, power series, Taylor theorem, zeros of an analytic function, Schwarz lemma.
4. Isolated singularity. Laurent’s theorem, classification of isolated singularities: pole, essential singularity, removable singularity, residues, Casorati-Weierstrass theorem. 5. Meromorphic function, Rouche’s theorem, Inverse function theorem, open mapping theorem, Cauchy residue theorem. Contour integration.
6. Maximum module theorem, convex function, Hadamard three circle theorem. Many-valued function, Branches of many-valued function, branch points. Conformal transformation, Bilinear transformation, cross ratio.
7. Method of analytic continuation, Schwarz reflection theorem, analytic continuation along a path, power series method of analytic continuation, Monodromy theorem.
8. Harmonic function: Harmonic function on a disk, Harnack’ inequality, Harnack’ theorem, Poisson integration formula.

References:

1. J.B.Conway ,Functions of a one complex variable, Narosa publishing house,1973
2. W.Rudun, Real and Complex Analysis, McGrawHill
3. H.S.Kasana, Complex Variable, Prentice Hall of India,2005
4. S.Punnusamy, Foundations of Complex Analysis, Narosa publishing house,2005
5. L.V.Ahlfors, Complex Analysis, McGrawHill,1979
6. Churchill,Complex Variables and Applications, McGrawHill

MATH 703C
Ordinary & Partial Differential Equations (Credit-4)

1. **First order ordinary differential equation:** Singular solution, initial value problem of first order ODE, general theory of homogeneous and non-homogeneous linear ODE,Basic theorems, Ascoli-Arzoli theorem, theorem on convergence of solution of initial value problem, Picard-Lindeloff theorem, Piano's existence theorem. Independence of the solution of linear differential equation, Wronskian and its properties, exact differential equation and equation of special form.
2. General theory of homogeneous and non-homogeneous linear ODEs, variation of parameters, Sturm-Liouville boundary value problems, Green's function.
3. First Order P D E: Formation of partial differential equations, Pfaffian differential equations - Quasi-linear equations, Lagrange's method, compatible systems, Charpit's method, Cauchy problem for first order partial differential equations.
4. **Second Order P D E:** Classification of second order PDE's, Linear PDE with constant coefficients, reducible and irreducible equations. Different methods of solution.
Second order PDE with variable coefficients. Characteristic curves of second order PDE. Reduction to canonical forms. D'Alembert's solution of wave equation. Solutions of PDE of second order by the method of separation of variables.

Reference:

1. Simmons, G. F. Differential Equations with Applications and Historical Notes,(McGraw Hill, 1991).
2. Codington and Levison, Theory of Ordinary Differential equations, Tata McGrawHill
3. Hertman, Ordinary Differential equations, John Wiley
4. W.T.Reid, Ordinary Differential equations
5. J.C.Burkill, Ordinary Differential equations
6. Ian Sneddon, Elements of Partial Diff.Equations
7. Rao, K.S. Introduction to partial differential equations (Prentice Hall of India, New Delhi, 2006).
8. Weinberger H.F., Intro. to Partial Diff.Equations

MATH 801C
Abstract Algebra (Credit-4)

1. **Groups(revision):** Groups, subgroups, cyclic groups, permutation groups, cosets, Lagrange's theorem. Normal subgroups, quotient groups.
2. **Group homomorphisms**: Definition and examples, properties of homomorphisms; Isomorphisms, Isomorphism theorems, Cayley's theorem, Automorphisms of groups.
3. **Direct products**: Definition and examples of external direct products, properties of external direct products, definition and examples of internal direct products, fundamental theorem of finite Abelian groups and applications.
4. **Group Action**: Definition and examples, properties of group action, Extended Cayley's theorem, Conjugacy classes, class equation, Cauchy's theorem, p-groups**,** Sylow's theorems, Simple groups, determination of simple groups of different orders, Structure of finite Abelian groups.
5. **Subnormal Series**: Sub-normal series, normal series, composition series, Jordan-Holder Theorem, solvable groups, nilpotent groups.
6. **Rings**: Rings, integral domains, fields; Ideals, Maximal ideal, prime ideal and primary ideal, factor rings, ring homomorphisms.
7. **Polynomial rings**: Polynomial rings, Factorization theory in integral domains, Principal ideal domain, Euclidean domains, Gaussian domain. Prime elements, irreducible elements, unique factorization domain, Einstein's irreducibility criterion and Gauss's lemma.
8. **Fields**: Fields, Field extensions, algebraic and transcendental extension, Classical ruler and compass constructions, Splitting fields and normal extensions, algebraic closures. Finite fields, Perfect fields, theorem of the primitive element Cyclotomic fields, Separable and inseparable extensions.

Reference

1. Gallian, J. A., Contemporary Abstract Algebra, 4th edition (Narosa Publishing house, New Delhi, 2009).
2. Dummit, D. S. & Foote, R. M., Abstract Algebra, 3rd edition (John Wiley & Sons, Indian reprint, New Delhi, 2011).
3. Herstein, I. N., Topics in Algebra, 2nd edition (John Wiley & Sons, Indian reprint, New Delhi, 2006).
4. Fraleigh, J. B. A First Course in Abstract Algebra, 7th edition (Pearson Education India, New Delhi, 2008).
5. Lang, S. Algebra, 3rd edition (Springer India, New Delhi, 2006).
6. Gopalakrishnan, N. S. University Algebra (New Age International (P) Ltd, New Delhi, 2001).

MATH 802C
Topology (Credit-4)

1. Topological spaces: Topological structures, accumulation points, closed sets, closure of a set, interior, exterior, boundary , neighbourhood & neighbourhood system, convergence and limit , coarser and finer topologies, subspaces, relative topologies, equivalent definition of topologies.
2. Bases and sub-bases: Base for a topology, sub base, topologies generated by classes of sets, local bases.
3. Continuity and topological equivalence : Continuous function, continuity at a point, sequential continuity at a point, open and closed functions, homomorphic spaces, topological properties, topologies induced by functions.
4. Separation axioms : Separation by open sets, separation axioms and T_i spaces, subspaces, sum, product and quotient spaces, Urysohn's lemma and Metrization theorem, completely regular spaces.
5. Countability: First countable spaces, second countable spaces, separation spaces and Lindeloff theorem. Hereditary properties.
6. Compact Spaces: Covers, compact sets, sub set of a compact space, finite intersection property, compactness and Hausdorff spaces, sequentially compact sets, locally compact sets.
7. Connectedness: Separated sets, connected sets, connected spaces, connectedness on the real lines.
8. Metrizable spaces : Definition and examples, properties, subspaces, product of metrizable spaces.
9. Function Spaces : Pointwise convergence, uniform convergence, the compact open topology, equi-continuity mutual relationship. Ascoli's theorem.

References:
1. B.C.Chatterjee, S.Ganguly, M.R.Adhikary, A Text Book of Topology, Asian Books Pvt. Ltd.
2. J. L. Kelly, General Topology, Von Nostradon 1066.
3. J. R. Munkres, Topology- A first Course
4.K. D. Jhoshi, Introduction to General Topology, Weyley Eastern.
5. S. W. Davis, Topology, Tata McGrow Hill.
6. S. William, General Topology, Addiotson Wesley.

MATH 803C
Mathematical Methods (Credit-3)

1. Linear Integral Equations: Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Eigen values and eigen functions, resolvent kernel.
2. Calculus of Variations: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema.Variational methods for boundary value problems in ordinary and partial differential equations.
3. Classical Mechanics: Generalized coordinates, Lagrange's equations, Hamilton's canonical equations, Hamilton's principle and principle of least action, Two-dimensional motion of rigid bodies, Euler's dynamical equations for the motion of a rigid body about an axis, theory of small oscillations.

References:

1. Brown J. W. and Churchill, R. Fourier Series and Boundary Value Problems (McGraw Hill, 1993).
2. Roach, G. F. Green's Functions (Cambridge University Press, 1995).
3. Gupta, A, S. Calculus of Variations with Applications (Prentice Hall of India, New Delhi 2003).
4. Mikhlin, S. G. Integral equations (The MacMillan Company, New york, 1964).
5. Lokenath Debnath and Dambaru Bhatta, Integral Transforms and Their Applications (Chapman & Hall/CRC)

MATH 901C
Fuzzy Set Theory (Credit-3)

1. **Fuzzy sets**: Definition of fuzzy sets, fuzzy point, α-level sets, convex fuzzy sets, basic operations on fuzzy sets, cardinality of fuzzy sets and relative cardinality of fuzzy sets.
2. **Operation on** F**uzzy sets**: Cartesian products, algebraic products, bounded sum and difference, t-norms and t-conorms, quasi-coincidence of two fuzzy sub sets, rough sets(definition and example), idea of soft sets.
3. **Generalization and variants of fuzzy sets**: L- fuzzy sets, interval- valued fuzzy sets, type -2 fuzzy sets, intuitionistic fuzzy sets and set operations of intuitionistic fuzzy sets, Zadeh's extension principle.
4. **Fuzzy Arithmetic**: Fuzzy numbers, triangular fuzzy numbers, fuzzy numbers describing 'Large' , Fuzzy numbers in the set of integers , arithmetic operations on intervals and fuzzy numbers.
5. **Fuzzy relations and fuzzy graphs**: Fuzzy relations on fuzzy sets, composition of fuzzy relations, max-min and min-max compositions, basic properties of fuzzy relations, relation between max-min and min-max compositions.
6. **Fuzzy order** : Fuzzy pre order relations, fuzzy semi pre order relations and fuzzy order relations, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy graphs, fuzzy similarity relations, examples of different fuzzy relations.
7. **Fuzzy functions**: Fuzzy functions on fuzzy sets, image and inverse image of fuzzy sets and some basic theorems on fuzzy functions.
8. **Fuzzy matrix**: Sum, multiplication of two fuzzy matrices, idempotent fuzzy matrix and their properties.

References:

1. H. J. Zimmermann, Fuzzy Set Theory and its applications, Allied publications Ltd. 1991.
2. G. J. Klir and B. Yuan, Fuzzy sets and Fuzzy Logic, Prentice Hall of India, 1995.
3. G. Bojadziev and M. Bojadziev , Fuzzy Sets, Fuzzy Logic, Applications, World Sci., 1995.
4. A. Mukherjee and S. Bhattacharya(Halder), Fuzzy Set Theory and Fuzzy Topology, Narosa, 2014.

MATH 902C
Functional Analysis (Credit-4)

1. Normed linear Space, Banach space, Quotient space of normed linear space and its completeness. Equivalent norms.
2. Riesz lemma, basic properties of finite dimensional normed linear space and compactness.
3. Weak convergence and bounded linear transformations, normed linear space of bounded linear transformations, Dual space, Reflexive space. Uniform boundedness theorem and some of its consequence.
4. Open mapping and closed graph theorem, Hahn-Banach theorem, weak sequential compactness, compact operators.
5. Inner product space, Hilbert space, Orthonormal sets, Bessel's inequality, complete orthonormal sets and Perseval's identity. Structure of Hilbert space, projection theorem.
6. Riesz representation theorem, Adjoint of an operator on a Hilbert space, reflexivity of Hilbert space. Self-adjoint operators, projection, normal and unitary operators.
7. Introduction to Spectral properties of Bounded Linear Operators.
8. Introduction to Banach Algebra and C* Algebra.

References:

1. P.K.Jain, O.P.Ahuja, & K.Ahmed, Functional Analysis, New Age Publications,2004
2. B.K.Lahiri, Elements of Functional Analysis, The World Press Pvt. Ltd.
3. A.H.Siddiqui, Functional Analysis with Applications, Anamaya publications
4. E.Kreyszing, Introductory Functional Analysis with Applications, John Wiley & Sons,1978
5. B.V.Limay, Functional Analysis, New Age Publications
6. G.F.Simmons, Introduction to Topology and Modern Analysis, TataMcGrawHill.
7. J.B.Conway, A Course in Functional Analysis,Springer,2008

MATH 903C
Computer Programming (C and MATLAB)
(Credit-2)

1. (C programming)

Review of basic concepts of C, Loops and decisions: for loop, while loop, do…while loop, if statement, if…else statement, switch statement, conditional operators, the break statement, the continue statement, goto statement.

Arrays and pointers, Structures, Function in C, Bubble sort, selection sort, insertion sort, linear search and binary search, C pre-processor.

2. (MATLAB Programming)

Basic Features: Simple Math, The Matlab workspace, About variables, complex number, floating point arithmetic, Mathematical functions. **Script M files**: Use, Block comments and code cells, startup and finish. **Array and Array operations**: Simple array, Array addressing or indexing, Array construction, Array orientation, scalar Array Mathematics, array Manipulation, Array sorting, Sub array searching, Array size, Array and Memory utilization, Multidimensional Array construction & its manipulation.**Numeric data type**: Integer data type, floating point data types.

Cell Arrays and structures: Cell array creation, its manipulation, Retrieving cell array content, comma separated list, cell functions, cell array of strings, structure creation, structure manipulation, structure functions. **Character string**: String construction, string evaluation, string functions, cell array of strings. **Relational and logical operations**: Relational and logical operators, Relational and logical functions, Nans and empty, operator precedence. **Control flow**: For loops, while loops, if else end construction, switch case construction, Try catch blocks.

References:

1. Yashavant Kanetkar, Let us C, BPB Publications.
2. Balaguruswamy, E. Programming in ANSI C (Tata McGraw-Hill, 2004).
3. Duane Hnselman, Bruce Littlefeild, Mastering MATLAB 7, Pearson Education India.
4. William J Palm III (Author), Introduction to MATLAB 7 for Engineers (Paperback), Tata McGraw-Hill.

MATH 904C
Numerical Analysis (Credit-2)

1. **Solutions of non linear algebraic equations**: Roots of Polynomial equations: Sensitivity of Polynomial Roots , Steffensen method, Bairstows method of quadratic factors, Graeffe's root squaring method, convergence of methods, rate of convergence.
2. Matrices and eigen value problem: LU decomposition of matrices, Power method of extreme eigen values , Jacobi's method for symmetric matrices.
3. Integration: Gauss-Legendre and Gaussain Chebyshev's quadrature, Richardson extrapolation, Euler Maclaurin's sum formula, Romberg's integration.
4. Ordinary Differential equations: First order equation: existence, uniqueness, stability of solution, Picard method, Euler's method, modified Euler's method, Multi step predictor corrector method, Runge-Kutta method.

References :

1. Ralston A , S. A first course in Numerical Analysis, Mc Graw Hill , N. Y(1965)
2. Conte SD , Boor, C de, Elementary numerical analysis (An algorithmic approach) MC GrawHill, Kogakusho. Ltd
3. Hildebrand, F. B. Introduction to Numerical Analysis, Mc GrawHill N. Y
4. Ames W. F. Numerical methods for Partial Differential equations , Academic press N.Y. 1977

MATH 1001C
Lebesgue Measure and Integration (Credit-3)

1. **Measurable Sets**: Length of Sets, Outer Measure, Lebesgue Measure, properties of measurable sets, Borel Sets & their measurability, further properties of measurable Sets, characterization of measurable sets, non- measurable sets.
2. **Measurable Functions**: Definitions, properties of measurable functions, step function, operations on measurable functions, characteristic function, simple function, continuous function, sets of measure zero.
3. **Borel Measurable Functions**: Sequence of Functions, The Structure of Measurable Functions, Convergence in Measure(Egorn Theorem, Lusin's Theorem)
4. **Lebesgue Integration** : Lebesgue integration of single function, Lebesgue integral of a bounded function, Riemann Integral, comparison of Riemann integral & Lebesgue integral.
5. **Properties of the Lebesgue integral for bounded measurable functions**: Integral of non-negative measurable functions, general Lebesgue integral, improper integral.
6. **Lebesgue Sets**: Absolutely continuous functions, integral of the derivative.

References :

1. H.L.Royden, Real Analysis, Prentice-Hall.
2. W. Rudin, Principle of Mathematical Analysis, McGrawHill 1976.
3. P. K. Jain & V. P. Gupta, Lebesgue Measure & Integration, New Age International Pvt. Ltd.

MATH 1002C
Numerical Practical through Computer Programming
(C and MATLAB)(Credit-4)

Numerical Practical:
Practical Examination Consist of Two parts

I. C – Programming: The following topics are to be covered
1. Bairstow's method
2. Graffe's Root squaring method
3. Power Method
4. L.U. Decomposition Method
5. Romberg Integration
6. Muller Method
7. Adams Moulton Method
8. Newton's Method
9. Steffensen's Method
10. Least square method
11. Gauss Elimination method
12. Gauss Siedel Method
13. Gauss-Jacobi iteration method
14. Milne's Method
15. Runge Kutta Method
16. Newton's Divided Difference Formula

II. MATLAB Programming: The following topics are to be covered
1. Bisection Method
2. Newton Raphson Method
3. Trapezoidal Rule
4. Simpsons one-third rule
5. Power method
6. Regula Falsi Method
7. Steffensen's Method
8. Muller method
9. LU decomposition
10. Gauss elimination method
11. Gauss Siedel method
12. Langrange's Method of interpolation
14. Richardson's extrapolation
15. Runge Kutta Method
16. Cubic spline approximation
17. Finite difference solution (ODE)
18 Adams Moulton method.

MATH 704E
Linear Algebra (Credit-4)

1. Vector spaces over fields, subspaces, bases and dimension, direct sum, row space, column space, rank, consistency and solution of system of linear equations.
2. Linear transformations and projections, the algebra of linear transformations, representation of linear transforms by matrices, rank-nullity theorem, Change of basis.
3. Eigen values and Eigen vectors, Theorems on Eigen values and Eigen vectors, Cayley-Hamilton theorem, Properties of characteristic polynomials, annihilating polynomials, minimal polynomials, triangularization and diagonalization of matrices.
4. Primary Decomposition theorem, Secondary decomposition theorem, Rational and Jordan canonical forms and some applications.
5. Inner product spaces, orthonormal basis, Gram-Schmidt orthogonalization process.
6. Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia, positive definiteness.

REFERENCES:

1. Hoffman and Kunze, Linear Algebra.
2. Rao A.R., Bhimashankaram P., Linear Algebra. (Tata Mc-Graw Hill)
3. M. Artin, Algebra, Prentice Hall of India.
4. S. Lang, Linear Algebra, Undergraduate Texts in Mathematics, Springer-Verlag.
5. P. Lax, Linear Algebra, John Wiley & Sons.
6. H.E. Rose, Linear Algebra, Birkhauser.
7. 3000 solved problems in Linear Algebra, Schaum's series.
8. Gareth Williams, Linear Algebra with applications, Narosa Publishing House.

MATH 705E
Operations Research (Credit-4)

1. **Inventory Control**: Inventory problems and their analytical structure, Economic lot size models with uniform rate of demand, with different rate of demand in different cycle**,** Simple deterministic and stochastic model of inventory control.
2. **Queuing theory**: Basic characteristics of queuing system, Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.
3. **Network analysis**: PERT,CPM,Project Crashing, Time cost Trade-off procedure
4. **Advanced topics in Linear Programming**: Revised simplex method, Duality theory, Dual Simplex method, Sensitivity analysis and Parametric Programming.
5. **Integer programming**: Importance of Integer programming problems. Gomory's All IPP technique, Cutting plane algorithm, Branch and bound technique.
6. **Dynamic programming**: Characteristic of Dynamic programming, Bellman's principle of optimality, forward and backward recursive approach, solving linear and non-linear programming problem, solution of inventory problems.

References:

1. F.S.Hiller & G.C.Leiberman, Int. to Operation Research, McGraw-Hill,1995
2. G.Hadly, Nonlinear and Dynamic Programming, Addison Wesley.
3. Kanri Swarup, P.K.Gupta & Man Mohan, Macmillan.
4. K.P.P.Chong, Stanislaw H.Zak, An Int. to Optimization, John Welly & Sons, 2001
5. J.K. Sharma, Operations Research: Theory and Applications, McMillan, 2013.

MATH 706E
Logic (Credit-4)

1. Syntax and semantics of propositional logic: Proposition, propositional connectives, truth value and truth table, validity, tautologies, adequate set of connectives.
2. Axiomatic approach of propositional logic: Axiomitazation, Modus-Ponens, deduction theorem, definition of theorem, proof in propositional logic, soundness theorem, compactness theorem, completeness theorem.
3. Syntax of first-order languages: First order languages, Term of a Language, Formulas of a language, First order theories.
4. Semantics of first order languages: Structure of first order languages, truth in structure, Model and elementary classes, embedding and isomorphisms, homogeneous structures, downward Lowenheim-Skolem theorem, definability.
5. Completeness theorem for first order logic: Proofs in first order logic, Metatheorem in first order logic, consistency and compactness, completeness theorem, interpretation in theory.
6. Model theory: Application of the completeness theorem, upward Lowenheim-Skolem theorem, ultra-product of models, applications in algebra, extension of partial elementary maps, elimination of quantifiers and applications, real closed fields and applications in algebra and geometry.

References:

1. Meldelson, E.: Int. to Mathematical Logic, 5e. CRC Press, Taylor and Francis Group, 2010
2.Margaris: First Order Logic, Dover
3. Srivastavas, S.M.: A Course on Mathematical Logic, Springer, 2013

MATH 805E
Set Theory (Credit-4)

1. Set and class, Axiomatic set theory, Zermelo-Franklen axiomatic set theory, comparison with other popular axiomatic set theory.
2. Partially ordered set, transfinite set, ordinal numbers, successor ordinal, limit ordinal, transfinite sequence.
3. Cardinal comparability, cardinal numbers, Schroder-Bernstein theorem, Cantor theorem, alephs, cofinality, regular and singular cardinal, limit cardinal, Tarski's theorem, Dedekind finite set.
4. Real numbers, continuum hypothesis(CH), Axiom of Choice(AC), well-ordering principle, maximum principle.
5. Cardinal arithmetic, sum and product of cardinals, generalized continuum hypothesis(GCH), transitive closure.
6. Transitive models, von Neomann theorem, isomorphism theorem, well foundedness, reflection principle, Godel operators.
7. Constructible set, Consistency of AC and GCH, Godel's theorems.

References:

1. Meldelson, E.: Int. to Mathematical Logic, 5e. CRC Press, Taylor and Francis Group, 2010
2. Kunen: Set Theory
3. Levy, A: Set Theory, Dover
4. Letcture on Set Theory, Springer, 1970

MATH 806E
Discrete Mathematics (Credit-4)

1. Combinatorics: Pigeon-hole principle, inclusion-exclusion principle, derangements. Generating functions. Polya's enumeration theory. Recurrence relations.
2. Boolean algebra : Lattices and Algebraic Systems, Principle of Duality, Basic Properties of Algebraic Systems, Distributive and Complemented Lattices, Boolean Lattices and Boolean Algebra, Uniqueness of Finite Boolean Algebra, Boolean expressions and Boolean functions, sum of product, product of sum, minterm, maxterm, minimization of Boolean functions, Karnaugh map method, Design and Implementation of Digital Neworks, Switching Circuits.
3. Graph theory : Basic concepts, definitions and examples, degree of vertex, subgraphs, complete graph, connected graph, walk, path, cycles, matrix representation of graph, adjacency matrix, incidence matrix, path matrix, Warshall's algorithm, planar graph, 5-colour theorem. Chromatic numbers.Eulerian path, tournament and Hamiltonian path. Directed graphs, in degree and out degree of a vertex, weighted undirected graphs, Dijkstra's algorithm, trees, binary trees, spanning trees, minimal spanning trees, Kruskal's algorithm. Matchings and Hall's Marriage Theorem. Eigen values of graphs.

References

1. Martin Erickson and Anthony Vazzana, Introduction to Number theory, Chapman and Hall/CRC.
2. I. Niven and H.S. Zuckerman, An Introduction to the Theory of Numbers, 4th Edition, Wiley, 1980.
3. D. B. West, Introduction to Graph Theory, Prentice Hall of India, 2001.
4. J. A. Bondy and U. S. R. Murty, Graph Theory with Applications, Springer-Verlag, 2008.
5. R. Diestel, Introduction to Graph Theory, Springer-Verlag, 2010.
6. Foulds, L. R. Graph Theory Applications (Narosa Publishing House, New Delhi, 1992).
7. Wilson, R. J. Introduction to Graph Theory (Longman, England, 1996).

. MATH 906E
Advanced Topology (Credit-4)

1. Cardinality and ordinality.
2. Metrizable Space, Urysohn‘s metrization theorem, Nagata-Smirnov metrization theorem.
3. Function Space-Pointwise convergence, uniform convergence, the compact-open topology, equi-continuity, mutual relationships, Ascoli’s theorem.
4. Zero-sets and their properties, cozero-sets, C-embedding and C*-embedding, pseudocompact space and its properties, Z-filters and Z-ideals, Z-ultrafilters.
5. Paracompact spaces, local finite refinement, Michael’s theorem, fully normal spaces, Stone’s coincidence theorem. A.H.Stone’s theorem, partition of unity and paracompactness.
6. Locally compact spaces and properties, K-spaces, Alexandroff compactifications. Stone-Cech compactification, applications of compactification theorem. Real compact spaces and characterizations.

References:

1. Gillman and Jerison, Rings of Continuous Functions, Springer-Verlag,1976
2. Porter and Woods, Extensions and Absolutes of H’d spaces,Springer Verlag,1987
3. Alo and Shapiro,Normal Topological Spaces, Cambridge University Press,1974
4. J.Nagata,Modern Genaral Topology, North Holland
5. J.Dugundji,Topology,Prentice Hall of India,2003
6. C.E.Aull,Rings of Continuous functions,Marcel Dekker Inc.1985
7. R.C.Walker,The Stone-Cech Compactifications,Springer Verlag,Berlin,1974.

MATH 907E
Differential Topology (Credit-4)

1. Calculus and Manifolds in R^n - Continuity and differentiability of function from R^n to R^m, Inverse function theorem, Implicit function theorem, the existence and uniqueness theorem of solution of ODE.
2. Multivariable integration, Sard's theorem, Exterior Algebra, differential forms, exterior differentiation, integration on singular chain.
3. Manifolds and submanifolds in R^n, tangent space, smooth map between to manifolds, immersion, submersion, embedding.
4. Orientation on manifolds, differential forms on manifolds, integration on manifolds. Concept of manifolds with boundary.
5. Abstract Manifolds – Topological manifolds, Differentiable manifolds, Smooth maps between two manifolds, diffeomorphism. Tangent space: Tangent vector, tangent space,
6. Derivative of a smooth map between two manifolds, Tangent bundle. Immersion, submersion, embedding, submanifold. Regular and critical point, Whitney weak embedding theorem, statement of Whitney embedding theorem, Morse's theorem and Morse function.
7. Vector field, Lie bracket, integral curve of a vector field, flows and local flows, existence of integral curve, complete vector field, existence of complete vector field, vector fields related by a differentiable map.
8. Concept of abstract manifolds with boundary.

References:

1. A.R.Shastri, Elements of Differential Topology, CRC Press, 2011
2. J.R.Muncres, Analysis on Manifolds, Addi-Wesley Pub.Co., 1991
3. S.Kumeresan, A Course in Differential Geometry and Lie Groups,Hindusthan Book Agencies,New Delhi,2002
4. U.C.De and A.A.Shaikh, Differential Geometry of Manifolds,Narosa Publishing House,2007
5. D.B.Gauld, Differential Topology-An Introduction, Dover, 1982
6. S.Boothby, An Introduction to Differentiable Manifolds and Riemannian Geometry, Accademic Press,1975
7. F.W.Warner, Foundations of Differentiadle Manifolds and Lie Groups, Springer Verlag,1983

MATH 908E
Rough Sets and Applications (Credit-4)

Rough Sets: Basic concepts of Rough sets, Approximation of sets, rough equality and rough inclusion of sets, comparison of rough sets, core, reduct, knowledge reduction. Algebraic and topological representation of rough sets, generalised approximation spaces, rough sets.
Variable Precision Rough Set: Basic concepts, properties, examples; Attribute reduction, significance of attribute reduction.
Probabilistic Rough set: Basic concepts, properties, examples; Attribute reduction, significance of attribute reduction.
Bayesian Rough set: Basic concepts, properties, examples; Attribute reduction, significance of attribute reduction.
Decision Theoretic Rough set: Basic concepts, properties, examples; Attribute reduction, significance of attribute reduction.
Applications of Rough Sets:
(a) Decision making, simplification of decision tables, decision algorithm, the case of incomplete information.
(b) Data Analysis, flow graphs, the case of inconsistent data, data mining.
(c) Rough sets and conflict analysis, concepts of conflict theory and applications.

References:
1. Z. Pawlak, Rough Sets, Kluwer Academic Publishers, 1991.

MATH 1004E
Fuzzy Logic and Applications (Credit-4)

1. Fuzzy logic: Overview Classical logic, fuzzy propositions, fuzzy quantifiers, linguistic variables and hedges, Inference from conditional fuzzy propositions, inference from conditional and quantified propositions, inference from quantified propositions.
2. Fuzzy membership: Fuzzy triangular membership, trapezoidal membership, direct method with one expert, indirect method with one expert, direct method with multiple experts, indirect method with multiple experts, Fuzzy relation, Fuzzy t-norm, Fuzzy co-norm.
3. Pattern recognition: Fuzzy clustering, Fuzzy pattern recognition, Fuzzy image processing.
4. Fuzzy Decision making: Individual decision making, multi-person decision making, multi-criteria decision making, multi-stage decision making, Fuzzy ranking method.
Applications of fuzzy logic:
(a) Fuzzy logic control and Applications, Modeling and control parameter, if then rules, rule evalutions, conflict resolution, defuzzification, washing machine, predator-prey system.
(b) Models of neurons: Neural and fuzzy machine intelligence, fundamental of neural networks, Fuzzy Automata, Fuzzy Dynamic system.

References:
1. G.J.Klir and B.Yuan, Fuzzy Sets and Fuzzy Logic, Prentice Hall of India, 1995.
2. G.Bojadziev and M.Bojadziev, Fuzzy Sets, Fuzzy Logic, Applications, World Sci,1995.
3. Yen and Langani, Fuzzy Logic, Pearson Education, 2003

MATH 1005E
Fuzzy Topology (Credit-4)

1. **Fuzzy topology:** Chang's definition and Lowen's definition, basic concepts, fuzzy open sets, fuzzy closed sets, fuzzy interior & fuzzy closure , fuzzy continuous function, lower (upper) semi continuous functions, their basic properties, subspaces, product spaces, quotient spaces, intuitionistic fuzzy topological spaces.
2. **Induced fuzzy topology**: Concept of induced fuzzy topology, weakly induced fuzzy topology–their basic properties, Relation between induced fuzzy topological space and its corresponding topological space, initial topological spaces.
3. **Separation axioms in fuzzy topological spaces**: Fuzzy T_0 space, fuzzy T_1 space, fuzzy Hausdorff space, fuzzy regular space, fuzzy normal space, properties and examples of these spaces.
4. **Fuzzy filter and fuzzy net**: Properties of fuzzy filter and fuzzy net, fuzzy filter base and their properties, fuzzy cluster point. Convergence of fuzzy net
5. **Fuzzy compact spaces**: Fuzzy open cover, α-shading (α*-shading), fuzzy compactness in the sense of Chang, fuzzy compactness in the sense of Lowen, Comparison between different compactness, N – compactness and its properties.
6. **Fuzzy connected space and fuzzy countability axioms**: Fuzzy countable axioms, q-separated sets, definition of fuzzy connectedness, examples and its properties, good extension of connectedness.
7. **Mixed Fuzzy Topology**: Definition and Different types of mixed fuzzy topology and their properties

References:

1. N. Palaniappan, Fuzzy Topology, Norosa 2006.
2. H. J. Zimmermann, Fuzzy Set Theory and its applications, Allied publications Ltd. 1991.

MATH 1006E
Sequence Space, Summability Theory & Applications (Credit-4)

1. Classical sequence spaces, Linear Space, Linear metric spaces, paranorms, semi-norms, norms, subspaces, dimensionality, factor space, basis, dimension, basic facts of normed linear spaces and banach spaces, Separability, Reflexivity and other properties.
2. Frechet spaces, FK-spaces and BK spaces, Schauder basis and AK-property, Continuous, Kothe-Toeplitz and generalized Kothe-Toeplitz duals of various sequence spaces.
3. Matrix transformations, Regular, Conservative and Schur matrices, Some other matrix transformations of classical sequence spaces. Strong and weak convergence and Schur property, Continuous and compact linear operators and their applications in matrix transformations.
4. Summability, Cesaro means, Special matrix method, Tauberian theorem.

Reference:

1. Element of Functional Analysis by I.J. Maddox, Cambridge University Press,1970
2. Summability Theory and Its Applications, F.Basar, Bentham Science Publisher, 2012
3. Elements of Metric Spaces by Mursaleen, Anamaya Publ. Company, 2005.
4. Regular Matrix Transformations, G.M.Peterson
5. Sequence spaces and series, P.K.Kamthan & M.Gupta

MATH 1007E
Riemannian Geometry (Credit-4)

1. Tensors, Exterior Forms, Covariant derivative, Affine Connection and existence theorem, Torsion and Symmetric connection.
2. Riemannian metric, existence of Riemannian metric, Riemannian connection, existence of Riemannian connection. Riemann curvature, sectional curvature, Ricci tensor, scalar curvature, Schur's theorem.
3. Parallel vector fields and Geodesics, Complete Riemanian Manifolds, Holf-Rinow's Theorem, Hadamard theorem, Manifolds with constant curvature.
4. Parametrised surface, Gause lemma. Totally geogesic submanifold. First and second variation of arc-lenghth and Energy.
5. Jacobi Vector fields, theorem of Bonnet-Myers and Synge-Weinstein, The theorem of Rauich, Morse index theorem, the sphere theorem.
6. Riemanian submersion, Isometric immersion: Riemannian submanifol, second fundamental form of a Riemannian submanifold, Gauss equation, Ricci equation, Coddazi equation.

References:

1. U.C.De and A.A.Shaikh , Differential Geometry of Manifolds,Narosa Publishing House,2007
2. S.Kumeresan, A Course in Differential Geometry and Lie Groups,Hindusthan Book Agencies,New Delhi,2002
3. J.M.Lee, Int. to Topological Manifolds, Springer, 2000
4. A.Mukherjee,Topics in Differential Topology,Hindusthan Book Agency, 2005
5. S. Gallot, D. Hulin, J. Lafontaine: Riemaninan Geometry, Springer Verlag, 1987
6. M.P. do Carmo: Riemanian Geometry, Birkhauser, 1992
7. A.A.Kosinski,Differentiable Manifolds,Accademic Press, 1993

MATH 1008E
Algebraic Topology (Credit-4)

1. Category, functors and natural transformations, topological categories, morphisms, sub-categories.
2. The Fundamental group: Homotopy, contractible spaces and homotopy type, fundamental group and properties, simply connected spaces, the fundamental groups of circle.
3. Finite Simplicial Complexes: Simplicial complexes, polyhedra and triangulations, simplicial approximation.
4. Simplicial Homology: Orientation of simplicial complexes, simplicial chain complexes and homology.
5. Integral homology groups. Induced homomorphisms, degree of map, invariance of homology groups.
6. Singular chain complex, one-dimensional homology and fundamental groups, Mayer-Vietoris sequence, singular cohomology and cohomology algebra. Chain complexes and homology, exact homology sequence theorem. Covering spaces.

References:

1. S.De,Algebraic Topology, Hindusthan Book Agency,(2003)
2. G.E.Bredon ,Topology & Geometry, Springer(1993)
3. J.M.Lee, Int. to Topological Manifolds, Springer(2000)
4. J.R.Munkress,Toplogy,Prentice Hall of India(2003)
5. J.W.Vick,Homology theory an Int. to Algebraic Topology, Springer Verlag(1994)
6. J.J.Rotman.An Int. to Algebraic Topology, Springer(1988)
7. Hatcher, Algebraic Topology, Cambridge University Press

MATH 1009E
Number Theory (Credit-4)

1. Congruences, Residue classes, linear congruences, Fermat's theorem, Euler'e theorem, Chinese Remainder theorem, Wilson's theorem, Order of an element mod n, primitive roots, existence of primitive roots, some applications.
2. Quadratic congruences, quadratic residues and non-residues, Quadratic reciprocity, the Jacobi symbol, some applications.
3. Divisor functions, perfect numbers, Mobius inversion, Fermat numbers, Mersenne Numbers, finding large primes, Continued fractions, Pythagorean triples, Gaussian integers, Pell's equation.
4. Divisibility and Euclidean algorithm, congruences, applications to facoting. Finite fields,
5. Legendre symbol and quadratic reciprocity, Jacobi symbol. Cryptosystems, diagraph transformations and enciphering matrices, RSA Cryptosystem. Primality and Factoring,
6. Pseudoprimes, Carmichael no, Primality tests, Strong Pseudoprimes, Monte Carlo method, Fermat factorization, Factor base, Implication for RSA, Continued fraction method.
7. Elliptic curves - basic facts, Elliptic curves over R, C, Q, finite fields. Hasse's theorem (without proof), Weil's conjectures (without proof), Elliptic curve cryptosystems, Elliptic curve factorization -Lenstra's method.

References:

1. Martin Erickson and Anthony Vazzana, Introduction to Number theory, Chapman and Hall/CRC.
2. V.K. Krishnan, Elementary Number Theory- A Collection of Problems with Solutions, University Press.
3. W.W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd Edition, Wiley Eastern, 1972.
4. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, 1984.
5. Neal Koblitz, A Course in Number Theory and Cryptology, Graduate Texts in Mathematics, Springer (1987).
6. Rosen M. and Ireland K., A Classical Introduction to Number Theory, Graduate Texts in Mathematics, Springer (1982).
7. David Bressoud: Factorization and Primality Testing, Undergraduate Texts in Mathematics, Springer (1989).