SYLLABUS FOR PG MATHEMATICS

DEPARTMENT OF MATHEMATICS
NAGALAND UNIVERSITY
LUMAMI

Approved by 41st AC, June 2025: Notification dated 30-06-2025

Course Structure

Abbreviations: **T** = Contact hours (Theory), **P** = Contact hours (Practical), **CR** = Credits, **MATC =** Mathematics Compulsory paper, **MATCBCP**= Choice Based Credit paper.

Semester	Course Code	Course Title	Total Marks	CR
I	MATC 101	Analysis on Metric Spaces	100	4
	MATC 102	Linear Algebra	100	4
	MATC 103	Complex Function Theory	100	4
	MATC 104	Normed Linear spaces and Fourier Series	100	4
	MATC 105	Discrete Mathematics	100	4
Total			**500**	**20**
II	MATC 201	Algebra	100	4
	MATC 202	Measure Theory - I	100	4
	MATC 203	Programming in C (Theory and Practical)	100	4
	MATC 204	Point set Topology -I	100	4
	MATC 205	Several Variable Calculus	100	4
Total			**500**	**20**
A student can exit after second semester with PG Diploma				
III	MATC 301	Topological Groups	100	4
	MATC 302(A)	MOOCS	50	2
	MATC302(B)	Point Set Topology -II	50	2
	MATC 303	Measure Theory - II	100	4
	MATC 304	Number Theory	100	4
	MATC 305	Theory of Field Extensions	100	4
Total			**500**	**20**
IV	MATC 401	Numerical Analysis	100	4
	MATC 402	Numerical Analysis (Practical) and Latex	100	4
	MATC 403	Functional Analysis	100	4
	MATC 404	Project Work	100	4
	MATCBCP4XY	Choice Based Credit Paper (CBCP)	100	4
Total			**500**	**20**
Grand Total			**2000**	**80**

Note:

1. A student with a four-year UG Honours or UG Honours with Research will do the courses of Semester III and Semester IV to earn a PG degree.
2. MATCBCP4XY will correspond to the Course Code of the choice-based credit papers being offered in the fourth semester.
3. The Department will offer the following options for the Choice Based Credit Paper subject to availability of faculty specilaised in the concerned field.
   MATCBCP401: Ring Theory
   MATCBCP402: Algebraic Topology
   MATCBCP403: Mathematical Methods
   MATCBCP404: Commutative Algebra
   MATCBCP405: Stone-Cech Compactification of a Discrete Semigroup
4. Students may take desired papers from SWAYAM MOOCS for the choice based credit papers and may transfer the credits at the end of the course.

DETAILS OF SYLLABI

MATC101: Analysis on Metric Spaces

Unit - I

Metric spaces: definition and examples. Open and closed balls. Neighbourhoods, interior point, open set, interior of a set. Limit point of a set, closed set, closure of set, Subspaces.

Unit - II

Sequences in a metric space, Cauchy sequences. Complete Metric Spaces. Convergence in a metric space, dense sets. Limits, limits involving the point at infinity. Continuous functions on metric spaces equivalent characterizations of continuity, Generalization of the definition of continuity by inverse image of open sets and closed sets.

Unit - III

Uniform continuity, compact metric space: definition and examples. Sequentially compact, limit point compact and their equivalence. Theorems on compact spaces, continuous functions on compact metric spaces, Inverse of continuous functions defined on compact domain. compact sets in Euclidean spaces. Heine- Borel theorem.

Unit - IV

Connected metric space: definition and examples. Theorems on connected spaces. Path connected metric spaces: definition and examples. Relationship between connectedness and path connectedness.

Recommended Books:

1. Principles of Mathematical analysis, W. Rudin, McGraw Hill Education, 2013.
2. Introduction to topology and modern analysis, G.F. Simmons, 2016.
3. Topology of metric spaces – S. Kumaresan, McGraw Hill Education (Narosa),2005
4. Mathematical Analysis, T.M. Apostol, Narosa,2002.
5. T. Tao Analysis II, Hindustan Book Agency.

MATC102: Linear Algebra

Unit - I

Vector spaces, linear independence; linear transformations, matrix representation of a linear transformation; isomorphism between the algebra of linear transformations and that of matrices.

Unit - II

Similarity of matrices and linear transformations; trace of matrices and linear transformations, characteristic roots and characteristic vectors, characteristic polynomials, relation between characteristic polynomial and minimal polynomial; Cayley-Hamilton theorem (statement and illustrations only); diagonalizability, necessary and sufficient condition for diagonalizability.

Unit - III

Projections and their relation with direct sum decomposition of vector spaces; invariant subspaces; primary decomposition theorem, cyclic subspaces; companion matrices; a proof of Cayley-Hamilton theorem; triangulability; canonical forms of nilpotent transformations; Jordan canonical forms; rational canonical forms.

Unit - IV

Inner product spaces, properties of inner products and norms, Cauchy-Schwarz inequality; orthogonality and orthogonal complements, orthonormal basis, Gram-Schmidt process; adjoint of a linear transformation; Hermitian, unitary and normal transformations and their diagonalizations.

Forms on inner product spaces and their matrix representations; bilinear forms; Hermitian forms; symmetric bilinear forms; orthogonal diagonalization of real quadratic forms.

Textbooks:

1. Linear Algebra (2^{nd} edition) – K. Hoffman and R. Kunze, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. Topics in Algebra (4^{th} edition) – I. N. Herstein, Wiley EasternLimited, NewDelhi, 2013.
3. Linear Algebra, A Geometric Approach – S. Kumaresan , Prentice-Hall of India Pvt. Ltd., New Delhi, 2001.
4. First Course in Linear Algebra – P. B. Bhattacharya , S. K. Jain and S. R. Nagpal, Wiley Eastern Ltd., New Delhi, 2000.
5. Finite Dimensional Vector Spaces – P. R. Halmos, Va n Nostrand Inc., 1965.

MATC103: Complex Function Theory

Unit - I

Complex form of equations of straight lines, half planes, circles, etc.; Complex derivatives of complex valued functions of a complex variable, the Cauchy- Riemann equations, holomorphic functions, holomorphic function as mappings; conformal maps; Mobius transformation; cross ratio; symmetry and orientation principle; examples of images of regions under elementary holomorphic functions like exponential function, the complex logarithm.

Unit - II

Brief survey of formal power series, radius of convergence of power series, analytic functions, exponential, cosine and sine, logarithm functions introduced as power series, their elementary properties.

Unit - III

Curves and Contours, Contour Integration, Fundamental theorem of calculus, the Cauchy-Gourset theorem, Cauchy's Integral formula, Liouville's theorem, Maximum Modulus Principle, Zeroes of Analytic/holomorphic functions.

Unit - IV

Taylor's series, Laurent series, Isolated singularities, residues, the Cauchy residue theorem, its application in evaluating real integrals, argument principle and Rouche's theorem.

Textbooks:

1. Complex Function Theory - Donald Sarason, Hindustan Book Agency.
2. Functions of one complex variable – J. B. Conway, Springer International Student edition, Narosa Publishing House, New Delhi, 2000.
3. Elementary theory of Analytic Functions of one or several complex variables- H. Cartan, Courier Dover Publications, New York, 1995.
4. Complex Analysis (2^{nd} Edition) – L. V. Ahlfors, McGraw-Hill International Student Edition, 1990.
5. Complex Variables and Applications – S. Ponnusamy, and H. Silverman, Birhkauser,2006

MATC104: Normed Linear Spaces and Fourier Series

Unit-I

Normed linear space, Banach space, definition and examples, Holder's inequality and Minskowski's inequality, open sets, closed sets in normed linear space, convergence and completeness.

Unit-II

Continuous linear transformation between normed linear space, characterisation of continuous linear transformation, the norm of a bounded linear transformation, isometric isomorphism.

Unit-III

Formal power series, real analytic functions, Abel's theorem, multiplication of power series, the substitution theorem, reciprocal of a power series, the exponential and logarithmic functions, trigonometric functions

Unit-IV

Periodic functions, inner products on periodic function, trigonometric polynomials, periodic convolution, the Fourier and Plancherel theorems.

Textbooks:

1. Introduction to topology and modern analysis, G.F. Simmons, 2016.
2. Topology of metric spaces – S. Kumaresan, McGraw Hill Education (Narosa),2005
3. Analysis-II (Third Edition), Terrence Tao, HBA.
4. Mathematical Analysis, T. Apostol, Narosa Publishing House.

MATC105: DISCRETE MATHEMATICS

Unit-I

Mathematical logic: Fundamentals of logic, logic inferences, methods of proof of an implication, First order logic and other methods of proof, Rules of inference for qualified propositions, mathematical induction, partially ordered sets, Lattics, Chains and well ordered sets, Axiom of choice, Cardinal and Ordinal numbers, Camtor's Lemma, Set theoretic paradoxes.

Unit- II

Elementary Combinatorics: Principles of addition and multiplication, arrangements, Basics of counting, Combinations and Permutations, Binomial and Multinomial theorens, Pigeonhole Principle, The Inclusion- Exclusion Principles, Generating functions, Stirling Number, Catalan Number, Recurrence Relations.

Unit- III

Graphs and digraphs, Path, Cycles, Trails, Vertex degrees and counting, Isomorphisms and subgraphs, Eulerian Circuits, Hamiltonian cycle, Adjacency metrix, Shortest path algorithm, Directed graphs, Eulerian digraphs, Orientations and Tournaments, Trees and their properties, Spanning trees and Enumeration, Optimization and trees: Minimum Spanning tree, shortest path.

Unit- IV

Coloring of Graphs: Vertex coloring and upper bounds, Brook's theorem. Matching: Maximum Matchings, Hall's Matching condition, Min-Max theorem, Independent sets and covers. Planargraphs: Embedings and Eulers formula. Network flow: Flow and cuts, Maxflow-Min cut theorem, Application : Matching and Hall's Marriage Theorem

Recommended Books:

1. Discrete Mathematics and its Applications- Kenneth H. Rosen
2. Discrete and combinatorial Mathematics- Ralph P. Grimaldi
3. Discrete Mathematics, Ping Zhang, Gary Chartrand.
4. Concrete Mathematics- Graham, Knuth, Potashnick
5. Discrete Mathematics for Computer science and Mathematicians, Joe L. Mott, Abraham Kandel, Theodore P Baker
6. Introduction to Graphs Theory, Douglas B West.
7. J.P Tremblay and R.P. Manohar, Discrete Mathematics with Applications to Computer Science, McGraw Hill, 1989.
8. V.K Balakrishnan, Introductory Discrete Mathematics, Dover,1996.

MATC201: Algebra

Unit - I

A brief review of groups, their elementary properties and examples, subgroups, cyclic groups, homomorphism of groups and Lagrange's theorem; permutation groups, permutations as products of cycles, even and odd permutations, normal subgroups, quotient groups; isomorphism theorems, correspondence theorem.

Unit - II

Group action; Cayley's theorem, group of symmetries, dihedral groups and their elementary properties; orbit decomposition; counting formula; class equation, consequences for p-groups; Sylow's theorems (proofs using group actions)

Applications of Sylow's theorems, conjugacy classes in S_n and A_n, simplicity of A_n. Direct product; structure theorem for finite abelian groups; invariants of a finite abelian group (Statements only).

Unit - III

Basic properties and examples of ring, domain, division ring and field; direct products of rings; characteristic of a domain; field of fractions of an integral domain; ring homomorphisms (always unitary); ideals; factor rings; prime and maximal ideals, principal ideal domain; Euclidean domain; unique factorization domain.

Unit - IV

A brief review of polynomial rings over a field; reducible and irreducible polynomials, Gauss' theorem for reducibility of $f(x)$ $\mathbf{Z}[x]$; Eisenstein's criterion for irreducibility of $f(x)$ $\mathbf{Z}[x]$ over $\mathbf{Q}$, roots of polynomials; finite fields of orders 4, 8, 9 and 27 using irreducible polynomials over $\mathbf{Z}_2$ and $\mathbf{Z}_3$.

Textbooks:

1. Topics in Algebra (4th edition) – I. N. Herstein, Wiley Eastern Limited, New Delhi, 2003.
2. A First Course in Abstract Algebra (4th edition) – J. B. Fraleigh, Narosa Publishing House, New Delhi, 2002.
3. Abstract Algebra – D.S. Dummit, R.M. Foote, John Wiley&Sons (2003).
4. Basic Abstract Algebra (3rd edition) – P.B. Bhattacharya, S. K. Jain and S. R. Nagpal, Cambridge University Press, 2000.
5. Contemporary Abstract Algebra (4th edition) – J. A. Gallian, Narosa Publishing House, New Delhi, 1999.

MATC202 Measure Theory-I

Unit-I:
Outer measure of a subset of IR^n and its properties, computation of outer measure of a set in IR^n, outer measure is non- additive.

Unit-II:
Measureable set and its properties in IR^n, countable property, sigma algebra property, Borel property. Measureable function, characterisation of Measureable functions, construction of new measureable functions from the given measureable functions on IR^n.

Unit-III
Simple fuctions on IR^n, lebesque integral of simple functions, basic properties of lebesque integration of non-negative simple function, integration of non-negative measureable function in IR^n, properties of lebesque integral on non-ve measureable function on IR^n, lebesque Monotone convergence theorem, Fatou's lemma on IR^n.

Unit-IV:
Integration of absolutely integrable function on IR^n, definition of lebesque integral of absolutely integrable function on IR^n and its properties, Lebesque Dominated Convergence Theorem on IR^n, relation between Riemann integral and Lebesque integral, Fubini's Theorem.

Textbooks:
1. Analysis-II, Terrence Tao, HBA.
2. Measure Theory and Integration, G De Barra, New Age International Publishers.

MATC203: Programming in C (Theory and Practical)

Unit-I

Character sets for C; constants and variables in C; arithmetic expressions in C; assignment and multiple assignments and mode of statements in C; built-in functions and libraries in C; input and output statements in C; comment statements; data types; TYPE declarations; statement labels; elementary programs in C.

Unit - II

Logical IF statements in C; switch, break, continue GOTO statements in C; WHILE, FOR, DO WHILE loops in C, **I**Subscripted variables and arrays in C; array variables, syntax rules, use of multiple subscripts in arrays, reading and writing multi-dimensional arrays, for loops, for arrays in C; format specifications in C.

Practical:

The following programs are to be practised:

1. Pickinmg the maximum/minimu8m among three numbers usinf if-else.
2. Adding the digits of a number using while loop.
3. Determination of roots of quadratic equations, $Ax^2+Bx+C=0$ using if loop, switch statement.
4. Arranging given set of numbers in increasing/decreasing order, calculation of Mean.
5. Evaluation of sum of power series eg. e^x, sin x, cos x, log (1 + x).
6. Interchanging the components of a vector.
7. Evaluating a polynomial.
8. Addition, subtraction. Multiplication of a matrix, Transpose, determinant.
10. Programs using logical operators and functions.

Textbooks:

1. Computer Porgramming in C-V. Rajaraman, PHI
2. C programming language- Brian W. Kernighan, Dennis M. Ritchie, Pearson

MATC204: Point Set Topology-I

Unit - I

Definition and examples of topological spaces; basis and sub basis; dictionary order, order topology; subspace topology; Hausdorff spaces, closed set, limit popint.

Unit- II

Continuity, definition and examples, several equivalent characterisation of continuity, product topology; box topology; the metric topology.

Unit - III

Connected spaces, properties of connected sets; component, path component; local connectedness, local path-connectedness.

Unit - IV

Compact spaces; definition and examples, several results on compact spaces, limit point compact and sequentially compact spaces; finite product of compact spaces.

Textbooks:

1. Topology, a first course – J. R. Munkres, Prentice- Hall of India Ltd., New Delhi, 2000.
2. General Topology – J. L. Kelley, Springer Verlag, N ew York, 1990.
3. An introduction to general topology (2^{nd} edition) – K. D. Joshi, Wiley Eastern Ltd., New Delhi, 2002.
4. Introduction to Topology & Modern Analysis – G. F. Simmons, Tata McGraw Hill.
5. General Topology – J. Dugundji, Universal Book Stal l, New Delhi, 1990.

MATC205: Several Variable Calculus

Unit - I

Functions from $\mathbb{R}^n$ into $\mathbb{R}^m$, Limits and continuity, Partial derivative, Directional derivative, Continuously differentiable functions, Derivative, Uniqueness of derivative, Chain rule, Sufficient condition for a function to be differentiable, Jacobian matrix of the derivative.

Unit - II

Critical points – maxima, minima and saddle point, discriminant test to determine the nature of critical points, Hessian matrix and its application to determine the nature of the critical points, Gradient and its relationship with directional derivative, Partial derivatives of higher order, Schwarz's Theorem, Inverse Function Theorem, Implicit Function Theorem.

Unit - III

Riemann integration on $\mathbb{R}^n$ and its properties, Integration on non-rectangular regions, Multiple integral, Fubini's Theorem, Partitions of unity, Change of variables, Line integral and surface integral. Exercises on evaluation of surface area and volume using double and triple integrals.

Unit - IV

Line integral and surface integral, geometric interpretation, curl and divergence of vector-valued functions, Green's theorem, Stokes' theorem and Gauss' Divergence theorem: statements and proofs. Exercises on Green's theorem, Stokes' theorem and Gauss' Divergence theorem.

Recommended Books:

1. Functions of several variables – Wendell Fleming, Springer-Verlag, New York Inc,, 1977.
2. Calculus on manifolds: A modern approach to classical theorems of advanced calculus – Michael Spivak, CRC Press, 2018.
3. Principles of mathematical analysis – Walter Rudin, McGraw Hill Education, 2013.
4. Analysis -II , Terrence Tao, HBA 5. Advanced calculus – GB Folland, Pearson, 2002.

MATC301: TOPOLOGICAL GROUPS

Unit-I

Topological group- Definition and examples, homogeneous topological groups, system of neighbourhoods of identity, subgroup, normal subgroup.

Unit-II

Open map, closed map, quotient map, quotient top and quotient space, factor group, homomorphism, isomorphism, direct product of topological groups.

Unit-III

Connected and totally disconnected group and their properties, locally compact group and compact groups and their properties, local isomorphism, topological transformation groups.

Unit-IV

Semi-group, right topological semi-group, compact right topological semi-group, closure and product of ideals, semi-topological and Topological semi-groups.

Textbooks:

1. L.S. Pontryagin Selected Works, Volume II, Topological groups, Gordon and Breach Science Publishers.
2. An Introduction to Topological Groups - P.J. Higgins, Cambridge University Press.
3. A Course on Topological Groups, K. Chandrasekharan, HBA.
4. Topology, James R Munkres, Pearson.

MATC302(B): POINT SET TOPOLOGY - II

Unit -I

Locally compact space, one point compactification, separation axioms, regular space, completely regular space, normal space and their result.

Unit - II

Statement of Urysohn's lemma; Urysohn metrization theorem, statement of tietze's extension theorem, Stone-Cech Compactification , Tychonoff's theorem.

Textbooks:

6. Topology, a first course – J. R. Munkres, Prentice- Hall of India Ltd., New Delhi, 2000.
7. General Topology – J. L. Kelley, Springer Verlag, N ew York, 1990.
8. An introduction to general topology (2^{nd} edition) – K. D. Joshi, Wiley Eastern Ltd., New Delhi, 2002.
9. Introduction to Topology & Modern Analysis – G. F. Simmons, Tata McGraw Hill.
10. General Topology – J. Dugundji, Universal Book Stal l, New Delhi, 1990.

MATC303: Measure Theory-II

Unit I:

σ-algebra, Borel σ-algebra, definition of measure on σ-algebra, measureable space, properties of measureable space, outer measure on a non-empty set, Carathedory's Theorem.

Unit II:

Measureable set and its properties in IR^n, countable property, sigma algebra property, Borel property. Measureable function, characterisation of Measureable functions, contruction of new measureable functions from the given measureable functions on IR^n.

Unit III:

Integration of complex functions, Dominated Convergence Theorem, Mode of Convergence, Egoroff's theorem, L^p space, product measure, Fubini- Tonelli theorem.

Unit IV:

Signed measure and differentiation, Jordan Decomposition theorem, Hahn Decomposition theorem, Lebesque Random Nikodym Theorem.

Textbooks:

1. Real Analysis - Modern Techniques and their Application - Gerald B. Foland, John Wiley & Sons Inc.
2. An Introduction to Measure Theory - Terrence Tao, AMS.
3. Measure Theory - P. R. Halmos, Springer-Verlag.
4. Functional Analysis - W. Rudin, Mc-Graw Hill.
5. Real Analysis, third edition, by H. L. Royden, Macmillan Publishing co.inc, New York, 1999.

MATC304: Number Theory

Unit - I

Divisibility; Euclidean algorithm; primes; congruences; Fermat's theorem, Euler's theorem and Wilson's theorem; Fermat's quotients and their elementary consequences; solutions of congruences; Chinese remainder theorem; Euler's phi-function.

Unit - II

Congruence modulo powers of prime; power residues; primitive roots and their existence; quadratic residues; Legendre symbol, Gauss' lemma about Legendre symbol; quadratic reciprocity law; proofs of various formulations; Jacobi symbol.

Unit - III

Greatest integer function; arithmetic functions, multiplicative arithmetic functions (elementary ones); Mobius inversion formula; convolution of arithmetic functions, group properties of arithmetic functions; recurrence functions; Fibonacci numbers and their elementary properties.

Unit - IV

Diophantine equations-solutions of $ax+by=c$, $x^2+y^2=z^2$, $x^4+y^4=z^2$; properties of Pythagorean triples; sums of two, four and five squares; assorted examples of diophantine equations. Simple continued fractions, finite and infinite continued fractions, uniqueness, representatiom of rational and irrrational numbers as simple continued fractions, rational approximation to irrational numbers, Huruwitz theorem, basic facts of periodic continued

Textbooks:

1. An Introduction to the Theory of Numbers (6^{th} edition) – I. Niven, H. S. Zuckerman and H. L. Montegomery, John Wiley and sons, Inc., New York, 2003.
2. Elementary Number Theory (4^{th} edition) – D. M. Burton, Universal Book Stall, New Delhi, 2002.
3. History of the Theory of Numbers (Vol. II, Diophantine Analysis) – L. E. Dickson, Chelsea Publishing Company, New York, 1971.
4. An Introduction to the Theory of Numbers (6^{th} edition) – G. H. Hardy and E. M. Wright, The English Language Society and Oxford University Press, 1998.
5. An Introduction to the Theory of Numbers (3^{rd} edition) – I. Niven and H. S. Zuckerman, Wiley Eastern Ltd., New Delhi, 1993.

MATC305: Theory of Field Extensions

Unit - I

Extension fields, finite extensions; algebraic and transcendental elements, adjunction of algebraic elements, Kronecker theorem, algebraic extensions, splitting fields – existence and uniqueness; extension of base field isomorphism to splitting fields.

Unit - II

Simple and multiple roots of polynomials, criterion for simple roots, separable and inseparable polynomials; perfect fields; separable and inseparable extensions, finite fields; prime fields and their relation to splitting fields; Frobeniusendomorphisms; roots of unity and cyclotomic polynomials.

Unit - III

Algebraically closed fields and algebraic closures, primitive element theorem; normal extensions; automorphism groups and fixed fields; Galois pairing; determination of Galois groups, fundamental theorem of Galois theory, abelian and cyclic extensions.

Unit - IV

Normal and subnormal series, composition series, Jordan- Holder theorem(statement only), solvable groups, nilpotent groups, solvability by radicals, solvability of algebraic equations, symmetric functions, ruler and compass constructions, fundamental theorem of algebra.

Textbooks:

1. Topics in Algebra (4^{th} edition) – I. N. Herstein, Wiley Eastern Limited, New Delhi, 2003.
2. A First Course in Abstract Algebra (4^{th} edition) – J. B. Fraleigh, Narosa Publishing House, New Delhi, 2002.
3. Contemporary Abstract Algebra (5^{th} edition) – J. A. Gallian.
4. Basic Abstract Algebra (3^{rd} edition) – P. B. Bhattacharya, S. K. Jain and S. R .Nagpal, Cambridge University Press, 2000.
5. Basic Algebra I (3^{rd} edition) – N. Jacobson, Hindustan Publishing corpo ration, New Delhi, 2002.

MATC401: Numerical Analysis

Unit - I

A brief introduction to algebraic and transcendental equations and their roots; direct and iterative methods for determination of roots of these equations; initial approximations; bisection method, secant method, Regula-Falsi method, Newton-Raphson method for determination of roots of algebraic and transcendental equations; error analysis, rate of convergence and algorithm for each of these methods.

Unit - II

A brief introduction to systems of linear algebraic equations and their solutions, eigenvalue problem and its solution; direct and iterative methods; forward and backward substitution method; Cramer's rule; Gauss elimination method; Gauss-Jordan elimination method; Gauss-Jacobi iteration method; Gauss-Seidel iteration method; power method for eigenvalue problem; iterative method for matrix inversion; error analysis, rate of convergence and algorithm for each of these methods.

Unit - III

Lagrange and Newton interpolation; Lagrange interpolating polynomial and Newton divided differences interpolating polynomial; linear interpolation; Newton's divided difference interpolation and its generalizations; finite difference operators; relation between differences and derivatives; Gregory-Newton forward and backward difference interpolation; truncation error bounds and algorithm for each of these interpolations.

Unit - IV

Differentiation and integration; numerical differentiation; methods based on linear and quadratic interpolation with error of approximation; methods based on finite differences; optimum choice of step length; numerical integration; methods based on interpolation; determination of the error term; trapezoidal rule; Simpson's rule; error of integration; algorithms for numerical differentiation and integration. ODE and their numerical solutions; IVP ; error estimates; Euler-Richardson method, Runge-Kutta methods and Predictor-Corrector method; error analysis and algorithm for each of these methods; partial differential equations; finite-difference method with error analysis and algorithm.

Textbooks:

1. Numerical Methods for scientific and Engineering computation – M. K. Jain, S. R. K. Iyenger and R. K. Jain, New Age international publishers, New Delhi, 2003.
2. Fundamental of Computer Numerical Analysis – M. Fri edman and A. Kandel, CRC Press, Boca Raton, 1993.
3. Applied Numerical Analysis (5^{th} edition) – C. F. Gerald and P. O. Wheatley, Addison-Wesley, New York, 1998.
4. Introduction to Numerical Analysis (2^{nd} edition) – K. E. Atkinson, John Wiley, 1989.
5. Elementary Numerical Analysis: An Algorithmic Approach (3^{rd} edition) – S. D. Conte and C. de Boor, McGraw Hill, New York, 1980.

MATC402: Numerical Analysis (Practical) and Latex

Unit-I:

The following programs are to be practised:

1. Solving simple/algebraic/transcendental equations; Newton's method (real roots only),
2. Solutions of system of linear equations, using Gauss' elimination method.
3. Solutions of system of linear equations, using Gauss-Siedel Iterative method.
4. Matrix inversion using Gauss' elimination method.
5. Matrix inversion using Gauss-Jordan method.
6. Power method for finding largest Eigen value.
7. Interpolation using Lagrange's formula.
8. Interpolation using Newton's divided difference formula.
9. Numerical differentiation using Newton's formula.
10. Numerical differentiation using Lagrange's formula .
11. Numerical integration using trapezoidal rule.
12. Numerical integration using Simpson's rules.
13. Improving the numerical integral using Richardson's Extrapolation.
14. Numerical solutions of ordinary differential equations(initial value problems) using Euler-Richardson method.
15. Numerical solutions of ordinary differential equations(initial value problems) using Runge-Kutta method.
16. Numerical solutions of ordinary differential equations(initial value problems) using Predictor-Corrector method.

Unit-II

Online Overleaf access, Creating a Title, Sections, Command names, and arguments, Labelling Table of Contents, Font Effects, Comments & Spacing Special Characters, Line breaking. Lists, Tables, Figures - List of figures, Equations: Inserting Equations and Mathematical Symbols, Inserting References: Inserting the Bibliography Styles, Technical Report: Writing Thesis/project/report, Classes: article, book, report,Document Layout and Organization- Page Layout – Titles, Abstract Chapters, Sections, References, Equation References, citation.

Textbooks:

1. Guide to LATEX, fourth edition, Helmut Kopka, Patrick W.Daly
2. Latex for beginners- Murugan Swaminathan.
3. Programming in C with numerical methos- Kamal B Rojiani.

MATC403: Functional Analysis

Unit - I

General Banach Spaces-definition and examples, bounded linear transformation, continuous linear transformastion between normed linear spaces, Hahn-Banach theorem and its conseqences.

Unit - II

First Conjugate space, second conjugate space, Embedding of a normed linear space in its second conjugate space;reflexive space, strong and weak topologies; open mapping theorem and its consequences.

Unit - III

Projection map on a Banach space, closed graph theorem and its consequences, uniform bounded theorem and its consequences, conjugate of an operator.

Unit - IV

Hilbert's space, examples and simple properties, orthogonal complements, orthonormal set, Bessel's inequalities, complete orthonormal sets, Gram-Schmidt orthogonalization process, self adjoint operators, Normal and unitary operators, projections.

Textbooks:

1. Real Analysis (4^{th} edition) – H. L. Royden, Macmillan Publishing co. inc, New York, 1999.
2. Introduction to Topology and Modern Analysis (4^{th} edition) – G. F. Simmons, Tata McGraw -Hill Ltd., 2004.
3. Functional Analysis – W. Rudin, Tata McGraw hill Bo ok Company, 1974.
4. Functional Analysis – B. V. Limaye, Willy Eastern L td., 1991.
5. First course in Functional Analysis – C.Goffman and G. Pedrick, Prentice-Hall of India Pvt. Ltd, New Delhi, 1974.

MATC404: Project Work

The project work can be done in any of the areas, namely, Analysis, Algebra, Linear Algebra, Complex Analysis, Functional Analysis, Topology, ODE, PDE, Commutative Algebra, Feild Extensions, Number Theory, Several Variable Calculus.
Students will work on problems selected from any of the fields mentioned above.

MATCBCP401: Ring Theory

Unit - I

Basic concepts of rings, modules, operations on ideals and sub-modules; matrix rings, polynomial rings; direct products of rings; fields and division rings; idempotent and nilpotent elements in a ring.

Unit - II

Isomorphism theorems; exact sequences; the group of homomorphisms and its properties relative to exact sequences.

Unit - III

Direct sums and direct products of modules, external and internal direct sums, direct summands; Zorn's lemma, every vector space has a basis; free modules and projective modules; torsion free and torsion modules over commutative domains; exact sequences and projectivity.

Unit - IV

Injective modules, injectivity and divisibility over domains; exact sequences and injectivity; Baer's theorem and its elementary applications; simple modules, semisimple modules (as per Bourbaki); Schur's lemma.

Equivalent conditions for semisimple modules; Wedderburn structure theorem (only statement); characterization of semisimple rings via projective and injective modules.

Textbooks:

1. Elementary Rings and Modules – I. T. Adamson, Oliver and Boyd, Edinburgh, 1995.
2. Notes on Homological Algebra – J. J. Rotman, Van no strand, 1990.
3. Basic Algebra II (3rd edition) – N. Jacobson, Hindustan Publishing Corporation, New Delhi, 2002.
4. Algebra, Second Edition – S. Lang, Addison-Wesley, Massachusetts, 1984.
5. Algebra, Vol. 2: Rings – I. S. Luthar and I.B.S. Passi, Narosa Publishing House, New Delhi, 1999.

MATCBCP402: Algebraic Topology

Unit - I

Homotopy of paths, fundamental group of a topological space, fundamental group functor, homotopy of maps of topological spaces; homotopy equivalence; contractible and simply connected spaces; fundamental group of S^1, $S^1 \times S^1$ etc.

Unit - II

Calculation of fundamental groups of S^n ($n > 1$) using Van Kampen's theorem (special case); fundamental group of a topological group; Brouwer's fixed point theorem; fundamental theorem of algebra; vector fields, Frobenius theorem on eigenvalues of 3 x 3 matrices.

Unit - III

Covering spaces, unique lifting theorem, path-lifting theorem, covering homotopy theorem, applications, covering transformations, criterion of lifting of maps in terms of fundamental groups, universal coverings and its existence(statement only).

Unit - IV

Singular homotopy, reduced homology, Eilenberg-Steenrod axioms(wihtout proof), relation between H_1 and H_2 relative homology. Calculus of homology of S^2, Bower fixed point theorem for f: E_n -->E_n($n>2$) and its application to spheres and vector fields, Meyer- Vietoris sequence and its application.

Textbooks:

1. Topology, a first course – J. R. Munkres, Prentice- Hall of India Ltd., New Delhi, 2000.
2. Algebraic topology, a first course (2nd edition) – M. J. Greenberg and J. R. Harper, Addison-Wesley Publishing co., 1997.
3. Algebraic Topology – A. Hatcher, Cambridge University Press, 2002.
4. Algebraic Topology (2nd edition) – E. H. Spanier, Springer-Verlag, New Yor k, 2000.
5. An Introduction to Algebraic Topology – J. J. Rotma n, Graduate Text in Mathematics, No. 119, Springer, New york, 2004.

MATCBCP403: Mathematical Methods

Unit - I

Laplace transforms, properties of Laplace transform, inversion formula convolution, application to ordinary and partial differential equations; Fourier transform, properties of Fourier transform, inversion formula, convolution, Parseval's equality; Fourier transform of generalized functions, application of transforms to heat wave and Laplace equation.

Unit - II

Formulation of integral equations, integral equations of Fredholm and Volterra type, solution by successive substitution and successive approximation; integral equations with degenerate kernels.

Unit - III

Integral equations of convolution type and their solutions by Laplace transform,Fredholm's theorems; integral equations with symmetric kernel; eigenvalues and eigenfunctions of integral equations and their simple properties.

Unit - IV

Generalized functions; Minusinkski's operational calculus of one variable (algebra of addition and convolution of functions, ordered pairs of functions, convolution quotients of a function with a nonzero function), Dirac delta function.

Eigenvalue problem; ordinary differential equations of the Sturm-Liouville type; eigenvalues and eigenfunctions; expansion theorem; extrema properties of the eigenvalues of linear differential operators, formulation of the eigenvalue problem of a differential operator as a problem of integral equation.

Textbooks:

1. Laplace Transform Theory – M. G. Smith, Van Nostran d Inc., 2000.
2. Generalized Functions and Partial Differential Equations – G. E. Shilov, Bernard Seckler, Gordon and Breach, 1999.
3. Integral Equations – David Porter and David S. G. S tirling, Cambridge University Press, 1993.
4. The Use of Integral Transforms – I. N. Sneddon, Tat a McGraw Hill, New Delhi, 1974.
5. Lectures on integral equations – H. Widom, Van Nost rand, 1969.

MATCBCP404: Commutative Algebra

Unit - I

Preliminaries on rings and ideals; local and semilocal rings; nilradical and Jacobson radical; operations on ideals; extension and contraction ideals; modules and module homomorphisms; submodules and quotient modules; operations on submodules; annihilator of a module; generators for a module, finitely generated modules; Nakayama's lemma; exact sequences.

Unit - II

Existence and uniqueness of tensor product of two modules; tensor product of n modules; restriction and extension of scalars; exactness properties of tensor products; flat modules.

Unit - III

Multiplicatively closed subsets; saturated subsets; ring of fractions of a ring; localization of a ring; module of fractions and its properties; extended and contracted ideals in a ring of fractions; total ring of fractions of a ring.

Unit - IV

Primary ideals; *p*-primary ideals; primary decomposition, minimal primary decomposition, uniqueness theorems; primary submodules of a module. Chain conditions, ascending chain conditions on modules; maximal condition; Noetherian modules; descending chain condition; minimal condition; Artinian modules, their properties; Noetherian rings; Hilbert basis theorem; Artinian rings; structure theorem for Artinian rings.

Textbooks:

1. Introduction to Commutative Algebra – M. F. Atiyah and I. G. Macdonald, AddisonWesley, 2000.
2. Commutative Algebra – N. S. Gopalkrishnan.
3. Undergraduate Commutative Algebra – M. Reid, London Math. Soc. Student Texts, No. 29, 1995.
4. Algebra (Volume 2: Rings) – I. S. Luther and I. B. S. Passi, Narosa Publishing House, New Delhi, 1999.
5. Algebra (Volume 3: Modules) – I. S. Luther and I. B . S. Passi, Narosa Publishing House, New Delhi, 1999.

MATCBCP405: Stone-Cech Compactification of a Discrete Semigroup

Unit - I

Semigroup, idempotents, subgroups, ideals, idempotents and order, minimal left ideals and idempotents, Right Topological semigroup, compact right topological semigroup and its properties, closure and product of ideals.

Unit - II

The Stone-Čech compactification**,** Ultrafilters and their characterizations, principal ultrafilters and non -principal ultrafilters and their properties, the topological space βD and the basis for the topology on βD, Stone-Cech Compactification of a Discrete topological Space and its properties, Uniform limits via ultrafilters.

Unit - III

Extending the operation of a semigroup S to βS, definition and characterization of the members of p.q where p,q are elements of βS, commutativity in βS, algebra of non-principal ultrafilters.

Unit - IV

Syndetic sets, piecewise syndetic sets, thick sets and their characterizations, relation with K(βS), central Sets-definition and characterizations, interrelationship among the different notions of largeness of a set, Hindman's theorem.

Textbooks:

1. Algebra in Stone-Cech Compactification, Neil Hindman, Dona Strauss, 2012, De Gruyter.
2. Topics in Algebra of βS, P Adams, PhD Dissertation(2001), Hull University.
3. The Stone-Cech Compactification of a topological semigroup, J. Baker and R. Butcher, Math Proc. Cambridge Philosophical Society 80 (1976),103-107
4. Analysis on semigroups, J Berglund, H. Junghenn and P. Milnes, Wiley, N. Y. 1989
5. Recurrence in ergodic theory and combinatorial number theory, H. Furstenberg, Princeton University Press, Princeton, 1981