Syllabi applicable for Admissions in M. Sc. (Mathematics), 2017
## Scheme of Programme for M.Sc. Mathematics

### SEMESTER- I

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**Interdisciplinary courses offered by Mathematics Faculty (For PG students of other Centres)**

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- \( C_A \): Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)
- \( M_1 \): Mid-Term Test-1: Based on Subjective Type Questions (25%)
- \( M_2 \): Mid-Term Test-2: Based on Subjective Type Questions (25%)
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- \( T_M \): Total Marks

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### SEMESTER- II

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C_A: Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)
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Department of Mathematics and Statistics, CUPB

Semester-III

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Syllabi applicable for Admissions in M. Sc. (Mathematics), 2017
Semester-I

Course Title: Probability and Distribution Theory
Course Code: MAT.506
Total Hours: 60

Objectives:
The course is designed to equip the students with knowledge of various probability distributions and to develop greater skills and understanding of various inequalities for further studies.

Unit I (14 Lecture Hours)
Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems. Axiomatic approach to probability. Product sample spaces, conditional probability, Bayes’ formula.

Unit II (16 Lecture Hours)

Unit III (15 Lecture Hours)
Bivariate random variable and their joint, marginal and conditional p.m.fs. and p.d.fs, correlation coefficient, conditional expectation. Bivariate normal distributions. Moment generating and probability generating functions. Functions of random variables and their distributions using Jacobian of transformation and other tools. Probability Integral transformation, order statistics and their distributions (continuous case only), truncated distributions, compound distributions.

Unit IV (14 Lecture Hours)

Recommended Books:

Suggested Readings:
Course Title: Real Analysis
Course Code: MAT.507
Total Lectures: 60

Objective: The aim of this course is to make the students learn fundamental concepts of metric spaces, Riemann-Stieltjes integral as a generalization of Riemann Integral, Sequence and series of functions and some basic theorems.

Unit-I (15 Lecture Hours)
Set Theory: Finite, countable and uncountable sets
Metric spaces: Definition and examples, Open and closed sets, Compact sets, Elementary properties of compact sets, k-cells, Compactness of k-cells, Compact subsets of Euclidean space $\mathbb{R}^k$, Perfect sets, Cantor set, Separated sets, Connected sets in a metric space, Connected subsets of real line.

Unit-II (15 Lecture Hours)
Sequences in Metric spaces: Convergent sequences, Subsequences, Cauchy sequences, Complete metric space, Cantor’s intersection theorem, Category of a set and Baire’s category theorem. Examples of complete metric space, Banach contraction principle.

Unit-III (15 Lecture Hours)
Continuity: Limits of functions (in Metric spaces), Continuous functions, Continuity and compactness, Continuity and connectedness, Discontinuities, Monotonic functions, Uniform continuity.
Riemann Stieltje’s Integral: Definition and existence of Riemann Stieltje’s integral, Properties of integral. Integration and Differentiation. Fundamental Theorem of Calculus, 1st and 2nd Mean Value Theorems of Riemann Stieltje’s integral.

Unit-IV (15 Lecture Hours)
Sequences and series of functions: Problem of interchange of limit processes for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, equicontinuous families of functions, Stone Weierstrass Theorem.

Recommended Books:

Suggested Readings:
Objective: The course is an introductory course on point-set topology. It is designed in such a way that the students will have a working knowledge in general topology and be able to understand more advanced topics like Algebraic Topology, Differential Topology, Riemannian Geometry and allied areas.

Unit-I (16 Lecture Hours)

Unit-II (15 Lecture Hours)
Connected spaces, Connected subspaces of the real line, Components and path components, Local connectedness. Compact spaces, Sequentially compact spaces, Heine-Borel Theorem, Compact subspaces of the real line, Limit point compactness, Local –compactness and one point compactification.

Unit-III (15 Lecture Hours)

Unit-IV (14 Lecture Hours)
The Stone-Čech Compactification, Complete metric spaces, Compactness in metric spaces, Pointwise and compact convergence, Ascoli’s Theorem and Baire spaces.

Recommended Books:

Suggested Readings:
Syllabi applicable for Admissions in M. Sc. (Mathematics), 2017

Course Title: Linear Algebra
Course Code: MAT.509
Total Hours: 60

Objective:
The concepts and techniques from linear algebra are of fundamental importance in many scientific disciplines. The main objective is to introduce basic notions in linear algebra that are often used in mathematics and other sciences. The emphasis will be to combine the abstract concepts with examples in order to intensify the understanding of the subject.

Unit I (15 Lecture Hours)
Vector Space: Vector spaces, Subspaces, Direct sum of subspaces, Linear dependence and independence, Basis and dimensions, Linear transformations, Algebra of linear transformations, Matrix representation of a linear transformation, Rank and nullity of a linear transformation, Invariant subspaces. Change of basis,

Unit I (16 Lecture Hours)
Characteristic polynomial and minimal polynomial of a linear transformation, Cayley Hamilton theorem, Eigenvalues and eigenvectors of a linear transformation, Diagonalization and triangularization of a matrix, Characteristic polynomial and minimal polynomial of block matrices. Canonical forms, Diagonal forms, Triangular forms, Jordan canonical forms, rational canonical forms, Quotient spaces.

Unit III (15 Lecture Hours)
Linear functional, Dual space, Dual basis, Annihilators, Bilinear forms, Symmetric bilinear forms, Sylvester’s theorem, quadratic forms, Hermitian forms. Reduction and classification of quadratic forms.

Unit IV (14 Lecture Hours)
Inner product spaces. Norms and distances, Orthonormal basis, Orthogonality, Schwartz inequality, The Gram-Schmidt orthogonalization process. Orthogonal and positive definite matrices. The Adjoint of a linear operator on an inner product space, Normal and self-adjoint operators, Unitary and orthogonal operators,

Recommended Books:
2. V. Bist and V. Sahai, Linear Algebra, Narosa, Delhi, 2002.

Suggested Readings:
Course Title: Differential Equations
Course Code: MAT.510

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Total Hours: 60

Objective:
The objective of this course is to equip the students with knowledge of some advanced concepts related to differential equations and to understand some basic approaches to solve the ordinary and partial differential equation.

Unit-I (15 Lecture Hours)
Initial value problem, Boundary Value Problems, Lipchitz’s condition, Dependence of solution on initial conditions and on function. Existence and Uniqueness theorem (Picard’s Method), Non local existence of solutions.

General theory of homogenous and non-homogeneous linear ODEs: Solution of Linear Homogeneous Equations; Wronskian and Linear Indepandence, Reduction of the order of equation, Non-Homogeneous equations: Method of undetermined coefficients, Variation of parameters.

Unit-II (14 Lecture Hours)
Series Solutions of Second Order Linear Equations: Ordinary points, Regular and Irregular Singular points of second order linear ODEs, Power series solution near an ordinary point, Cauchy-Euler Equations, Solutions about Singular Points; The Method of Frobenius

Unit-III (14 Lecture Hours)
Total differential equations, Simultaneous differential equations, Adjoint and self adjoint equations, Green’s function and its applications to boundary value problems, Sturm Liouville’s boundary value problems. Sturm comparison and separation theorems, Orthogonal solutions.

Unit-IV (17 Lecture Hours)
Classification of Partial differential Equations (PDEs), Cauchy’s problem and Characteristics for first order PDEs, Lagrange’s linear PDEs, Charpit’s and Jacobi’s method. Well posed and Ill-posed problems, General solution of higher order linear PDEs with constant coefficients, Separation of variables method for Laplace, Heat and wave equations.

Recommended Books:

Suggested Readings:
Course Title: Basic Mathematics  
Course Code: MAT.503  
Total Hours: 30

Objective: The objective of this course is to provide the understanding of basic mathematical techniques for the post graduate students of the other departments.

Unit-I (08 Lecture Hours)
Sets: Basic Definitions, subsets, power set, set operations. Ordered pairs, Cartesian product of sets.
Functions and Relations: Definition of relation, domain, co-domain and range of a relation. Binary relations, equivalence relations, partition. Function as a special kind of relation from one set to another. Domain, co-domain and range of a function, composition, inverse. Real valued function of the real variable, constant, identity, Polynomial, rational, Functions.

Unit-II (07 Lecture Hours)
Sequence and series, Arithmetic Progression (A.P), Arithmetic Mean (A.M), Geometric Progression (G.P), general term of a G.P, sum of n terms of a G.P. Arithmetic and Geometric series, infinite G.P. and its sum. Geometric mean (G.M), relation between A.M and G.M.

Unit-III (08 Lecture Hours)
Need for complex numbers, especially √-1, to be motivated by inability to solve every Quadratic equation. Brief description of algebraic properties of complex numbers. Argand plane and polar representation of complex numbers, Statement of Fundamental Theorem of Algebra, n\textsuperscript{th} roots of unity.

Unit-IV (07 Lecture Hours)

Recommended Books:

Suggested Reading Books:
Semester-II

Course Title: Computer Fundamentals and C Programming
Course Code: MAT.521

Total Hours: 45

Objectives: The aim of this course is to provide adequate knowledge of fundamentals of computer along with problem solving techniques using C programming. This course provides the knowledge of writing modular, efficient and readable C programs. Students also learn the utilization of arrays, structures, functions, pointers, file handling and their applications.

Unit-I (10 Lecture Hours)
Computer Hardware: Definitions, Historical overview, Technological advancement in computers, Shape of today’s computer, Computer as a system. CPU, Primary memory, Secondary storage devices, Input and Output devices.

Unit-II (11 Lecture Hours)
Computer Software: Significance of software in computer system, Categories of software – System software, Application software, Compiler, Interpreter, Utility program, Binary arithmetic for integer and fractional numbers, Operating System and its significance. Introduction to algorithm, Flow charts, Problem solving methods, Need of programming languages.

Unit-III (12 Lecture Hours)
C Programming: Historical development of C, C character set, Identifiers and keywords, Data types, Declarations, Statement and symbolic constants, Input-output statements, Preprocessor commands, Operators, Expressions, Library functions, Decision making and loop control statements.

Unit-IV (12 Lecture Hours)
C Programming: Functions, Storage Classes, Arrays, Strings, Pointers, Structure and Union, File handling.

Recommended Books:

Suggested Readings:
Course Title: Computer Fundamentals and C Programming (LAB)

Course Code: MAT.522

Total Hours: 30

Laboratory experiments will be set in context with the materials covered in the theory.

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Course Title: Algebra – I
Course Code: MAT.523
Total Hours: 60

Objective:
This course provides the foundation required for more advanced studies in Algebra. The aim is also to develop necessary prerequisites for course Algebra-II.

Unit I  
Group Theory: Review of basic concepts of Groups, Subgroups, Normal subgroups, Quotient groups, Homomorphism, Cyclic groups, Permutation groups, Even and odd permutations, Conjugacy classes of permutations, Alternating groups, Cayley's Theorem, Class equations.

Unit II  
Normal and Subnormal series, Composition series, Solvable groups, Nilpotent groups. Direct products, Fundamental theorem for finite Abelian groups, Sylow theorems and their applications, Survey of some finite groups, Groups of order p^2, pq (p and q primes)

Unit III  

Unit IV  
Polynomial rings in many variables, Factorization of polynomials in one variable over a field. Unique factorization Domains. Euclidean and Principal ideal Domains. Gauss lemma, Eisenstein’s irreducibility criterion, Unique factorization in R[x], where R is a Unique factorization domain.

Recommended Books:

Suggested Readings:
Course Title: Measure Theory
Course Code: MAT.524
Total Hours: 60

Objective: The objective of this course is to introduce student’s measure theory in an abstract setting after having studied Lebesgue measure on real line. Some important theorems are also studied.

Unit-I (15 Lecture Hours)
Semi-algebras, Algebras, Monotone class, \( \sigma \)-algebras, Measure and outer measures, Caratheödory extension process of extending a measure on semi-algebra to generated \( \sigma \)-algebra, Completion of a measure space.

Unit-II (15 Lecture Hours)
Borel sets, Lebesgue outer measure and Lebesgue measure on \( \mathbb{R} \), Translation invariance of Lebesgue measure, Characterizations of Lebesgue measurable sets, Countable additivity, Continuity of measure and Borel-Cantelli Lemma, Existence of a non-measurable set, Measurability of Cantor set.

Unit-III (15 Lecture Hours)
Measurable functions on a measure space and their properties, Borel and Lebesgue measurable functions, Simple functions and their integrals, Littlewood’s three principle and Egoroff’s Theorem (statement only), Lebesgue integral on \( \mathbb{R} \) and its properties.

Unit-IV (15 Lecture Hours)
Bounded convergence theorem, Fatou’s lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem, \( L^p \) spaces, Young’s inequality, Minkowski’s and Hölder’s inequalities, Riesz-Fischer theorem (statement only).

Recommended Books:

Suggested Readings:
Course Title: Differential Geometry of Curves and Surfaces
Course Code: MAT.525
Total Hours: 60

Objective: To introduce students to the local and global theory of curves and surfaces so that they can embark on further studies and research in topics like Differential Topology, Riemannian Geometry and allied areas.

Unit-I (15 Lecture Hours)

Unit-II (15 Lecture Hours)

Unit-III (15 Lecture Hours)
Second fundamental form, Curvature of curves on a surface, Normal and Principal curvatures, Meusnier’s theorem, Euler’s theorem, Weingarten equations and Weingarten matrix, Geometric interpretation of principal curvatures, Umbilical points. Gaussian and Mean curvature, Pseudo sphere, Flat surfaces, Surfaces of constant mean curvature, Gaussian curvature of compact surfaces, Gauss map and its properties.

Unit-IV (15 Lecture Hours)
Geodesics: Definition and basic properties, Geodesic equations, Geodesics on a surfaces of revolution, Clairaut’s theorem, Geodesics as shortest paths, Geodesic coordinates, Gauss Theorema Egregium, Gauss equations, Codazzi-Mainardi equations, Compact surfaces of constant Gaussian curvature.

Recommended Books:

Suggested Readings:
Department of Mathematics and Statistics, CUPB

Course Title: Complex Analysis
Course Code: MAT.526
Total Lectures: 60

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Objective: This course is aimed to provide an introduction to the theories for functions of a complex variable. It begins with the exploration of the algebraic, geometric and topological structures of the complex number field. The concepts of analyticity, Cauchy-Riemann equations and harmonic functions are then introduced. Students will be equipped with the understanding of the fundamental concepts of complex variable theory.

Unit-I (15 Lecture Hours)
Review of complex number system, Algebra of complex numbers, Complex plane, Function of a complex variable, Limit, Continuity, Uniform continuity, Differentiability, Analytic function, Cauchy- Riemann equations, Harmonic functions and Harmonic conjugate.

Unit-II (15 Lecture Hours)
Complex line integral, Cauchy’s theorem, Cauchy-Goursat theorem, Cauchy’s integral formula and its generalized form, Index of a point with respect to a closed curve, Cauchy’s inequality. Poisson’s integral formula, Morera’s theorem. Liouville’s theorem, Contour integral, Power series, Taylor’s series, Higher order derivatives, Laurent’s series.

Unit-III (15 Lecture Hours)
Singularities of analytic functions, Fundamental theorem of algebra, Zeroes of analytic function, Poles, Residues, Residue theorem and its applications to contour integrals, Branches of many valued functions with arg z, log z, and z^a. Maximum modulus principle, Schwarz lemma, Open mapping theorem.

Unit-IV (15 Lecture Hours)
Meromorphic functions, The argument principle, Rouche’s theorem, Mobius transformations and their properties and classification, Definition and examples of conformal mappings.

Recommended Books:

Suggested Readings:
**Course Title:** Mechanics  
**Course Code:** MAT.527  
**Total Hours:** 30

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**Objectives:**
This course is designed for the M.Sc. students, but it is also useful for science or engineering students in related areas. The main goal of the course is to introduce the concept of mechanics and its applications and to learn the fundamentals of this important topic.

**Unit-I**  
(08 Lecture Hours)  
General force system, equipollent force system, equilibrium conditions, reduction of force systems, couples, moments and wrenches, necessary and sufficient conditions of rigid bodies, general motion of rigid body.

**Unit-II**  
(07 Lecture Hours)  
Moments and products of inertia and their properties, Moving frames of references and frames in general motion, Euler’s dynamical equations, Motion of a rigid body with a fixed point under no force.

**Unit-III**  
(08 Lecture Hours)  

**Unit-IV**  
(07 Lecture Hours)  
Lagrange’s equations through Hamilton’s principle, Cyclic coordinates and conservation theorems, Canonical equations of Hamilton, Hamilton’s equations from variational principle.

**Recommended Books:**

**Suggested Readings:**
3.  
Department of Mathematics and Statistics, CUPB

Course Title: Linear Programming
Course Code: MAT.504

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Objective: The objective of this course is to provide the understanding of Linear Programming for the post graduate students of the other departments.

Unit-I (08 Lecture Hours)
Formulation of linear programming problems (LPP). Graphical solution to LPPs. Cases of unique and multiple optimal solutions. Unbounded solutions and infeasibility and redundant constraints.

Unit-II (08 Lecture Hours)
Feasible solution, basic feasible solutions, Optimal solution, Convex sets, Solution of LPP with Simplex methods. The dual problem. Formulation of the dual.

Unit-III (08 Lecture Hours)
Transportation problems, Formulation of transportation problem, Feasible and optimal solution of transportation problems. Assignment problems.

Unit-IV (06 Lecture Hours)
Theory of games: Introduction to basic concepts of game theory including strategic Games.

Recommended Books:
Course Title: Numerical Methods  
Course Code: MAT.505  
Total Lectures: 30

Objective: The objective of this course is to provide the understanding and use of numerical methods for the post graduate students of other departments.

Unit-I (07 Lecture Hours)
Error Analysis: Relative error, Truncation error, Roundoff error, Order of approximation, Order of convergence, Propagation.

Unit-II (08 Lecture Hours)
Bisection method, Secant method, Newton Raphson method, Convergence and order of convergence.

Unit-III (07 Lecture Hours)
Interpolation and Polynomial Approximation, Lagrange’s Method, Newton’s polynomials.

Unit-IV (08 Lecture Hours)

Recommended Books:

Suggested Reading:
### Course Title: Research Methodology

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**Total Hours:** 30

### Objectives:

The objective of this course is to equip the students with knowledge of some basic as well as advanced concepts related to research. The course covers preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism etc.

### Unit-I

**Unit-I**

**Introduction:** Meaning, Objectives, Characteristics, Significance, and Types of Research; Research Approaches, Research Methods vs. Research Methodology, Research Process, and Criteria of Good Research.

### Unit-II

**Unit-II**

**Literature Survey and Review:** Meaning of Literature Survey and Review, Sources of Literature, Methods of Literature Review, and Techniques of Writing the Reviewed Literature. **Formulating Research Problem:** Understanding a Research Problem, Selecting the Research Problem, Steps in Formulation of a Research Problem, Formulation of Research Objectives, and Construction of Hypothesis.

### Unit-III

**Unit-III**


### Unit-IV

**Unit-IV**

**Report Writing:** Types of Reports – Technical and Popular Reports, Significance of Report Writing, Different Steps in Writing Report, Art of Writing Research Proposals, Research Papers, Project Reports, and Dissertations/Thesis; Basics of Citation and Bibliography/Reference Preparation Styles; Report Presentation: Oral and Poster Presentations of Research Reports.

### Recommended Books:


### Suggested Readings:

Objective:
This course is an advanced course in Algebra for students who wish to pursue research work in Algebra.

Unit-I

Field Theory: Basic concepts of field theory, Extension of fields, algebraic and transcendental extensions. Algebraically closed fields, splitting fields, separable and inseparable extensions, Normal extension, multiple roots, finite fields, perfect fields.

Unit-II

Modules: Definition and Examples, Submodules, Direct sum of submodules, Free modules, Difference between modules and vector spaces, Quotient modules, Homomorphism, Simple modules, Modules over PID.

Unit-III

Modules with chain conditions: Artinian Modules, Noetherian Modules, composition series of a module, length of a module, Hilbert Basis Theorem.

Unit-IV

Galois Theory: Automorphism groups, Fixed fields, Galois extensions, The fundamental theorem of Galois theory, Cyclotomic extensions, and Cyclic extensions, Applications of cyclotomic extensions and Galois theory to the constructability of regular polygons, Solvability of polynomials by radicals.

Recommended Books:

Suggested Readings:
3. V. Bist and V. Sahai, Linear Algebra, Narosa, Delhi, 2002.
Course Title: Calculus of Variation and Integral Equations
Course Code: MAT.552
Total Hours: 60

Objective:
The objectives of the course calculus of variations and integral equations is to develop knowledge of the basic tenets of the theory of integral equations and mastery of the respective solutions of problems and exercises, knowledge of the main provisions of the calculus of variations and the ability to use the concepts and methods of the theory in solving problems arising in theoretical and mathematical physics.

Unit-I (15 Lecture Hours)

Unit-II (15 Lecture Hours)
Sturm-Liouville’s theorem on extremals, one sided variations, Hamilton’s principle, Hamilton’s canonical equation of motion, The principle of least action, Lagrange’s equations from Hamilton’s principle. Variational Methods (Direct Methods, Euler’s finite difference method, The Ritz method, Kantorovich Method), for Boundary value problems in ODE’s & PDE’s, Isoperimetric Problems.

Unit-III (15 Lecture Hours)

Unit-IV (15 Lecture Hours)
Fredholm Equations: Solution by the method of successive approximations. Solution of Fredholm integral equation for degenerate kernel, Solution by the successive approximations, Neumann series and resolvent kernel.

Recommended books:

Suggested Readings:
Course Title: Numerical Analysis
Course Code: MAT.553
Total Hours: 45

Objective:
The aim of this course is to teach the applications of various numerical techniques for a variety of problems occurring in daily life. At the end of the course, the students will be able to do programming in C/C++/MATLAB and understand the basic concepts in Numerical Analysis of differential equations.

Unit-I (11 Lecture Hours)


Unit-II (12 Lecture Hours)

Polynomial Interpolation: Interpolating polynomial, Lagrange and Newton divided difference interpolation, Error in interpolation, Finite difference formulas, Hermite Interpolation.

Unit-III (11 Lecture Hours)

Spline and Approximation: Cubic Spline, Least square method, Pâde approximation
Eigen Value Problems: Power method.
Numerical Differentiation and Integration: Numerical differentiation with finite differences, Trapezoidal rule, Simpson's 1/3 - rule, Simpson's 3/8 rule, Error estimates for Trapezoidal rule and Simpson's rule, Gauss quadrature formulas.

Unit-IV (11 Lecture Hours)


Recommended Books:

Suggested Readings:
Course Title: Numerical Analysis (Lab)
Course Code: MAT.554
Total Hours: 30

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Objective: Laboratory experiments will be set in context with the materials covered in theory in C/C++/MATLAB.

Laboratory Work: Programming exercises on numerical methods using C/C++/MATLAB languages.

1. To detect the interval(s) which contain(s) root of equation $f(x)=0$ and implement bisection method to find root of $f(x)=0$ in the detected interval.
2. To find the root of $f(x)=0$ using Newton-Raphson and fixed point iteration methods.
3. To compute the intermediate value using the Newton’s forward difference interpolation formula.
4. To compute Lagrange and divided difference interpolating polynomials.
5. To solve linear system of equations using Gauss elimination (without pivoting) method.
6. To solve linear system of equations using Gauss-Seidel method.
7. To find the dominant eigenvalues and associated eigenvector by Rayleigh power method.
8. To integrate a function numerically using trapezoidal and Simpson’s rule.
9. To solve the initial value problem using Euler and modified Euler’s methods.
10. To solve the initial value problem using and Runge-Kutta methods.
Course Title: Seminar
Course Code: MAT.597
Total Hours: 60

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Total Hours: 60
Course Title: Differential Topology
Paper Code: MAT.555
Total Hours: 60

Objective: To introduce students to the basics of Differential Topology so that they are able to appreciate better the topics covered in allied courses like Algebraic Topology, Riemannian geometry and Riemann-Finsler geometry as well as be adequately prepared for pursuing research in these topics.

UNIT-I (15 Lecture Hours)
Topological Manifolds, Charts, Atlases, Smooth Manifolds, Examples of Smooth Manifolds, Manifolds with boundary, Smooth functions on a Manifold, Smooth maps between Manifolds, Diffeomorphism, Smoothness in terms of components, Examples of Smooth maps, Partial derivatives, and the Inverse function Theorem.

UNIT-II (15 Lecture Hours)
Tangent space and Tangent bundle, The Differential of a map, Chain rule, Bases for the Tangent space at a point, Curves in a manifold, Submersions, Immersions and Embeddings, Smooth covering maps, Critical and Regular points, Submanifolds, Rank of a smooth map, Submersion and Immersion Theorems, Bump functions and partition of unity, Sard’s Theorem, The Whitney Embedding theorem (Statement only).

UNIT-III (15 Lecture Hours)

UNIT-IV (15 Lecture Hours)

Recommended Books:

Suggested Readings:
Course Title: Advanced Partial Differential Equations
Course Code: MAT.556
Total Hours: 60

Objectives:
The objective of this course is to equip the students with knowledge of some advanced concepts related to partial differential equations and to understand some basic approaches to mathematical oriented PDEs.

Unit-I (16 Lecture Hours)
Distribution: Test Functions and Distributions, Examples, Operations on Distributions, Supports and Singular Supports, Convolution, Fundamental Solutions, Fourier Transform, Schwartz space, Tempered Distributions.
Sobolev Spaces: Basic properties, Approximation by smooth functions, Extension theorems, Compactness theorems, Dual spaces, Functional order spaces, Trace spaces, Trace theory, Inclusion theorem.

Unit-II (15 Lecture Hours)

Unit-III (14 Lecture Hours)

Unit-IV (15 Lecture Hours)

Recommended Books:
Course Title: Advanced Complex Analysis
Course Code: MAT.557
Total Hours: 60

Objectives:
This course is designed to enable the readers to understand further deeper topics of Complex Analysis and will provide basic topics needed for students to pursue research in pure Mathematics.

Unit–I
Harmonic function: Definition, Relation between a harmonic function and an analytic function, Examples, Harmonic Conjugate of a harmonic function, Poisson's Integral formula, Mean Value Property, The maximum & minimum principles for harmonic functions, Dirichlet Problem for a disc and uniqueness of its solution, Characterization of harmonic functions by mean value property.

Unit–II

Unit–III
Weierstrass Elliptic functions: Periodic functions, Simply periodic functions, fundamental period, Jacobi's first and second question, Doubly periodic functions, Elliptic functions, Pair of Primitive Periods, Congruent points, First and Second Liouville's Theorem, Relation between zeros and poles of an elliptic function, Definition of Weierstrass elliptic function (z) and their properties, The differential equation satisfied by (z) [i.e., the relation between (z) and (z)], Integral formula for (z),Addition theorem and Duplication formula for (z).

Unit- IV
Weierstrass Zeta function: Weierstrass Zeta function and their properties, Quasi periodicity of (z), Weierstrass sigma function (z) and their properties, Quasiperiodicity of (z), Associated sigma functions.

Recommended Books:

Suggested Readings:
Course Title: Discrete Mathematics
Course Code: MAT.558
Total Hours: 60

Objectives:
The objective of this course is to acquaint the students with the concepts in Discrete Mathematics. It includes the topics like logics, graph theory, trees and Boolean algebra.

Unit-I (14 Lecture Hours)

Unit-II (15 Lecture Hours)
Set Theory: Paradox in set theory, Inductive definition of sets and proof by induction; Peano postulates; Relations: Representation of relations by graphs, Properties of relations, Equivalence relations and partitions, Partial orderings, Linear and well-ordered sets;

Unit-III (16 Lecture Hours)

Unit-IV (15 Lecture Hours)

Recommended books:

Suggested Readings:
Course Title: Number Theory
Course Code: MAT.559
Total Hours: 60

Objective:
The objective of this course is to teach the fundamentals of different branches of Number Theory, namely, Geometry of Numbers and Analytic Number Theory.

Unit-I (15 Lecture Hours)
Divisibility of Integers, Greatest common divisor, Euclidean algorithm. The fundamental theorem of arithmetic, Congruences, Residue classes and reduced residue classes.

Unit-II (15 Lecture Hours)
Indices and its applications, Quadratic residues, Euler’s criterion, Product of quadratic residues and quadratic non-residues, The Legendre symbol and its properties, Gauss’s lemma, Quadratic reciprocity law, Jacobi symbol and its properties.

Unit-III (15 Lecture Hours)
Chinese remainder theorem, Fermat’s little theorem, Wilson’s theorem, Euler’s theorem. Arithmetic functions σ(n), d(n), τ(n), µ(n), Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots.

Unit-IV (15 Lecture Hours)
Representation of an integer as a sum of two and four squares. Diophantine equations ax + by = c, x²+y²=z² and its application to x⁴+y⁴=z⁴. Farey sequences, Continued fractions.

Recommended books:

Suggested Readings:
Course Title: Operations Research
Course Code: MAT.560
Total Hours: 60

Objective:
The objective of this course is to acquaint the students with the concept of convex sets, their properties, Linear and nonlinear programming problems. The results, methods and techniques contained in this paper are very well suited to the realistic problems in almost every area.

Unit-I (15 Lecture Hours)

Unit-II (15 Lecture Hours)

Unit-III (15 Lecture Hours)

Unit -IV (15 Lecture Hours)
Replacement problem, replacement of items that Deteriorate, replacement of items that fails completely. Job Sequencing Problems; Introduction and assumption, Processing of n jobs through two machines, Processing of n jobs through three machines and m machines, Processing two jobs through n machines.

Recommended books:

Suggested Readings:
Department of Mathematics and Statistics, CUPB

Semester-IV

Course Title: Functional Analysis
Course Code: MAT.571
Total Hours: 60

Objective: The objective of this course is to introduce basic concepts, methods of Functional Analysis and its Applications. It is a first level course in Functional Analysis.

Unit-I
Fundamentals of Normed Linear Spaces: Normed Linear spaces, Banach spaces and examples, finite dimensional normed spaces and subspaces, compactness and finite dimension. Quotient space of normed linear spaces and its completeness.

Unit-II
Weak convergence and bounded linear transformations, Normed linear spaces of bounded linear transformations, Dual spaces with examples.
Three Main Theorems on Banach Space: Uniform boundedness theorem and some of its consequences, Open mapping and closed graph theorems.

Unit-III

Unit-IV

Recommended books:

Suggested Readings:
Course Title: Project Work
Course Code: MAT.599
Total Hours: 120

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Course Title: Riemannian Geometry
Course Code: MAT.572
Total Hours: 60

Objective: The objective of the course is to introduce students to the basic concepts of Riemannian geometry to prepare them for further studies and research in Riemannian geometry, Finsler geometry, Mathematical Physics and their applications in allied areas.

Unit-I (16 Lecture Hours)
Review of differentiable manifolds and vector fields with examples, Covariant differentiation of vector fields and affine connection, Riemannian metric, Riemannian manifolds, Riemannian connection, Fundamental Theorem of Riemannian Geometry via Koszul’s Formula.

Unit-II (14 Lecture Hours)
Tensors and Tensor fields (Riemannian metric as the most significant example), Tensorial property, Covariant differentiation of tensor fields, Riemann curvature tensor, Ricci tensor, Definition of sectional, Ricci and scalar curvatures, Isometries, notion of covering spaces, pull-back metrics via diffeomorphisms.

Unit-III (16 Lecture Hours)
Covariant differentiation of a vector field along a curve with specific examples, Arc length and energy of a piecewise smooth curve, Geodesics as length minimizing curves, First variation of arc length, To show that geodesics are critical points of the fixed end point first variation formula, Exponential map, Geodesic completeness, Geodesic normal coordinates, Hopf-Rinow Theorem (statement only), Geodesic variations, Jacobi fields and Gauss lemma.

Unit-IV (14 Lecture Hours)
Second variation formula, the index form (Jacobi fields as minimizers of the Index form), Global differential geometry, spaces of constant sectional curvature, Bonnet-Myers, Cartan-Hadamard Theorem, Cartan’s Theorems (on determination of metric by curvature).

Recommended Books:


Suggested Readings:

Course Title: Fluid Mechanics
Course Code: MAT.573
Total Hours: 60

Objective:
The objective of this course is to introduce to the fundamentals of the study of fluid motion and to the analytical approach to the study of fluid mechanics problems.

Unit-I (15 Lecture Hours)
Real fluids and ideal fluids, velocity of fluid at a point, streamlines, path lines, streak lines, velocity potential, vorticity vector, local and particle rate of change, equation of continuity, irrigational and rotational motion, acceleration of fluid, conditions at rigid boundary.

Unit-II (15 Lecture Hours)
Euler’s equation of motion, Bernoulli’s equation, their applications, Potential theorems, Axially symmetric flows, impulsive motion, Kelvin’s theorem of circulation, equation of vorticity.

Unit-III (15 Lecture Hours)
Some Three Dimensional Flows: sources, sinks and doublets, images in rigid planes, images in solid sphere, Stoke's stream function.

Unit-IV (15 Lecture Hours)
Two Dimensional Flows: complex velocity potential, Milne Thomson circle theorem and applications, theorem of Blasius, vortex rows, Karman Vortex Street.

Recommended books:

Suggested Reading:
**Course Title:** Advanced Numerical Analysis

**Course Code:** MAT.574

**Total Hours:** 60

**Objectives:** The objective of the course is to familiarize the students about some advanced numerical techniques e.g. solving systems of nonlinear equations, linear system of equations, Eigen value problems, Interpolation and Approximation techniques and their use in differentiation and integration, differential equations etc.

**UNIT- I**

**Non-Linear Equations:** Methods for multiple roots, Muller’s, Iteration and Newton-Raphson method for non-linear system of equations, and Newton-Raphson method for complex roots.

**Polynomial Equations:** Descartes’ rule of signs, Birge-Vieta, Bairstow and Giraffe’s methods.

**System of Linear Equations:** Triangularization, Cholesky and Partition methods, SOR method with optimal relaxation parameters.

**UNIT-II**

**Eigen-Values of Real Symmetric Matrix:** Similarity transformations, Gerschgorin’s bound(s) on eigenvalues, Jacobi, Givens, Householder and Rutishauser methods.

**Interpolation and Approximation:** B - Spline and bivariate interpolation, Gram-Schmidt orthogonalisation process and approximation by orthogonal polynomial, Legendre and Chebyshev polynomials and approximation.

**UNIT- III**

**Differentiation and Integration:** Differentiation and integration using cubic splines, Romberg integration and multiple integrals.

**Ordinary Differential Equations:** Shooting and finite difference methods for second order boundary value problems, Applications of cubic spline to ordinary differential equation of boundary value type.

**UNIT- IV**

**Partial Differential Equations:** Finite difference methods for Elliptic, Parabolic and Hyperbolic partial differential equations.

**Recommended Books:**


**Suggested Readings:**


Syllabi applicable for Admissions in M. Sc. (Mathematics), 2017
Course Title: Algebraic Topology
Course Code: MAT.575
Total Hours: 60

Objective: The objective of this course is to introduce the student’s concept in Algebraic topology so that they can pursue research in this field and its allied areas.

Unit-I (14 Lecture Hours)

Unit-II (14 Lecture Hours)

Unit-III (16 Lecture Hours)

Unit-IV (16 Lecture Hours)

Recommended Books:

Suggested Readings:
Course Title: Lie Groups and Lie Algebra
Course Code: MAT.576
Total Hours: 60

Objective:
The aim of this course is to make the students learn basic concepts of Lie groups and Lie algebra, so as to enable the students to understand further topics related to solution of differential equations.

Unit I
(15 Lecture Hours)
Differential Manifolds Topological manifolds, Charts, Atlases and smooth structure, Smooth maps and diffeomorphism, Partitions of Unity, Tangent space, Tangent map, Vector fields and 1-forms.

Unit II
(15 Lecture Hours)
Lie Groups Definition and examples, Linear Lie groups, Lie group homomorphism, Lie algebra and the exponential map, Adjoint representation, Homogeneous spaces, Baker-Campbell-Housdorff formula.

Unit III
(15 Lecture Hours)
Lie Algebras Definition and examples, Classical Lie algebras, Solvable and nilpotent Lie algebras, Lie and Engel theorems, Semi-simple and reductive algebras, Semi-simplicity of Classical Lie algebras.

Unit IV
(15 Lecture Hours)
Semisimple Lie algebras; Killing form; Jordan decomposition; Engel's Theorem, Cartan subalgebra and Root space decomposition, Geometry of Root systems, Simple roots and Weyl group, Classification of root systems; Examples.

Recommended Books:

Suggested Readings:
**Department of Mathematics and Statistics, CUBP**

**Course Title:** Finite Element Analysis

<table>
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<th>Course Code: MAT.577</th>
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**Total Hours:** 60

**Objective:**
The aim of this course is to make the students learn fundamental concepts of finite elements so as to enable the students to understand further topics related to solution of differential equations. Finite element analysis is a helpful tool to solve a variety of problems of science and engineering related to fluid flows, structures etc.

**Unit-I**

(14 Lecture Hours)

General theory of finite element methods, Difference between finite element and finite difference, Review of some integral formulae, Concept of discretization, Convergence requirements, Different coordinates, One dimensional finite elements, shape functions, stiffness matrix, connectivity, boundary conditions, equilibrium equation, FEM procedure.

**Unit-II**

(16 Lecture Hours)

Generalization of the finite element concepts-weighted residual and variational Approaches (Ritz method, Galerkin method, collocation method etc.) Numerical integration, Interpolation formulas and shape functions, Axis symmetric formulations, solving one-dimensional problems.

**Unit-III**

(14 Lecture Hours)

Two dimensional finite element methods, Element types: triangular, rectangular, quadrilateral, sector, curved, isoperimetric elements and numerical integration, two dimensional boundary value problems, connectivity and nodal coordinates, variational functions, triangular elements and area coordinates, transformations, cylindrical coordinates.

**Unit-IV**

(16 Lecture Hours)

Three dimensional finite elements, higher order finite elements, element continuity, plate finite elements, Application of finite element methods to elasticity problems and heat transfer problems.

**Recommended Books:**


**Suggested Readings:**


Syllabi applicable for Admissions in M. Sc. (Mathematics), 2017