जननायक चन्द्रशेखर विश्वविद्यालय, बलिया

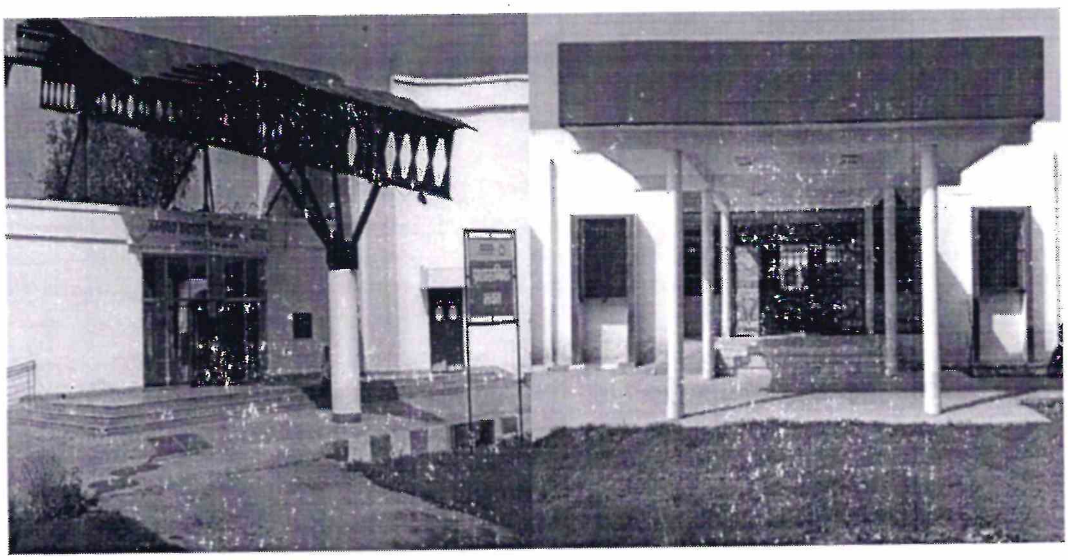
JANANAYAK CHANDRASHEKHAR UNIVERSITY, BALLIA

(A State University established under the Uttar Pradesh University Act 1973)

Curriculum in Accordance with

National Education Policy – 2020

Programme Name:	**B.Sc.**
Subject:	**Mathematics**



Department of Mathematics

Jananayak Chandrashekhar University, Ballia

Shaheed Smark, Near Surha Taal, Basantpur, Ballia – 277301, Uttar Pradesh, India

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Structure for Four Years Undergraduate Programme in accordance with National Education Policy-2020 and common minimum syllabus

(w.e.f. 2023-24)

MATHEMATICS

Year	Sem	Course code	Paper Title	Theory/ Practical	Credits	Total Credits
1st	I	B030101T	Differential Calculus & Integral Calculus	THEORY	6	6
	II	B030201T	Matrices and Differential Equations & Geometry	THEORY	6	6
2nd	III	B030301T	Algebra & Mathematical Methods	THEORY	6	6
	IV	B030401T	Differential Equation & Mechanic	THEORY	6	6
3rd	V	B030501T	Group and Ring Theory & Linear Algebra	THEORY	5	10
			Any one of the following-	Theory	5	
		B030502(A)T	Number Theory & Game Theory/			
		B030502(B)T	Graph Theory and Discrete Mathematics/			
		B030502(C)T	Differential Geometry & Tensor Analysis			
	VI	B030601T	Metric Space & Complex Analysis	THEORY	5	10
		B030602T	Numerical Analysis & Operations Research	THEORY	5	
4th	VII	B030701T	Algebra-I	Theory	5	20
		B030702T	Real Analysis	Theory	5	
		B030703T	Basic Topology	Theory	5	
		B030704T	Complex Analysis	Theory	5	
	VIII	B030801T	Algebra-II	Theory	5	20
		B030802T	Functional Analysis-I	Theory	5	
		B030803T	Measure & Integration-I	Theory	5	
			Any one of the following-	Theory	5	
		B030804(A)T	Classical Mechanics/			
		B030804(B)T	Special Theory of Relativity			

Note:

- The student shall prepare a Minor Research Project (MRP) in the 5th and 6th Semester (3rd Year) of Graduation. The MRP shall be submitted and evaluated in the 6th Semester.
- The student shall prepare a Research Project in the 7th and 8th Semesters (4th Year) of Graduation. The research Project shall be submitted and evaluated in the 8th Semester.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	I	
Course Code	BO30101T	
Course Title	DIFFERENTIAL CALCULUS & INTEGRAL CALCULUS	
Credit	6	Maximum Marks : 100

Course Objective: students will understand the concept of sequence and series, differentiation and integration and their application in solving problems related to mathematics and other sciences.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain the concepts of sequence, series, differentiation and integration.
2. Appreciate and describe the importance of calculus.
3. Relate different theorems related to these topics.
4. Apply these results in drawing graphs of functions.
5. Apply the results in solving problems related to mathematics, science and engineering.

Syllabus

Unit	**Course Content**
I	Definition of a sequence, theorems on limits of sequences, bounded and monotonic sequences, Cauchy's convergence criterion, Cauchy sequence, limit superior and limit inferior of a sequence, subsequence, Series of non-negative terms, convergence and divergence, Comparison tests, Cauchy's integral test, Ratio tests, Root test, Raabe's logarithmic test, de Morgan and Bertrand's tests. Limit, continuity and differentiability of function of single variable, Cauchy's definition, Heine's definition, equivalence of definition of Cauchy and Heine, Uniform continuity, Borel's theorem, boundedness theorem, Bolzano's theorem, Intermediate value theorem, extreme value theorem. Darboux's intermediate value theorem for derivatives, chain rule.
II	Rolle's theorem, Lagrange and Cauchy Mean value theorems, mean value theorems of higher order, Successive differentiation, Leibnitz theorem (statement and examples), Maclaurin's and Taylor's series (statement and examples), Partial differentiation, Euler's theorem on homogeneous function. Asymptotes, Curvature, Tracing of curves.

III	Definite integrals as limit of the sum, Riemann integral, Integrability of continuous and monotonic functions, Fundamental theorem of integral calculus. Improper integrals, their classification and convergence, Comparison test, μ-test, Abel's test, Beta and Gamma functions.
IV	Rectification, Volumes and Surfaces of Solid of revolution, Multiple integrals, change of order of double integration. Vector Differentiation, Gradient, Divergence and Curl, Normal on a surface, Directional Derivative, Vector Integration, Theorems of Gauss, Green, Stokes and related problems.

References:

1. R.G. Bartle & D.R. Sherbert, Introduction to Real Analysis, John Wiley & Sons.
2. T.M. Apostal, Calculus Vol. I, John Wiley & Sons Inc.
3. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, 2007.
4. 1. T.M. Apostal, Calculus Vol. II, John Wiley Publication.
5. Shanti Narayan & Dr. P.K. Mittal, Integral Calculus, S.Chand.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	II	
Course Code	B030201T	
Course Title	MATRICES AND DIFFERENTIAL EQUATIONS & GEOMETRY	
Credit	6	Maximum Marks : 100

Course Objective:

1. Students will learn about matrices, operations on them and their application in solving linear equations.
2. Students will learn about formation and meaning of differential equations, and methods to solve differential equations.
3. Students will learn about coordinate geometry and describe geometrical objects using analytical geometry.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain different types of matrices and operations on them.
2. Apply the matrices in solving linear equations.
3. Compare methods of finding inverse of a matrix and finding solution of linear equations.
4. Describe the origin and meaning of differential equations.
5. Solve differential equations using methods learned in the course.
6. Classify different types of conics, and describe different geometrical objects using analytical geometry.

Syllabus

Unit	Course Content
I	Types of Matrices, Elementary operations on Matrices, Rank of a Matrix, Echelon form of a Matrix, Normal form of a Matrix, Inverse of a Matrix by elementary operations, System of linear homogeneous and non-homogeneous equations, Theorems on consistency of a system of linear equations. Eigen values, Eigen vectors and characteristic equation of a matrix, Caley-Hamilton theorem and its use in finding inverse of a matrix.
II	Formation of differential equations, Geometrical meaning of a differential equation, Equation of first order and first degree, Equation in which the variables are separable, Homogeneous equations, Exact differential equations and equations reducible to the exact form, Linear equations. First order higher degree equations solvable for x, y, p, Clairaut's equation and singular solutions, orthogonal trajectories, Linear differential equation of order greater than one with constant coefficients,

	Cauchy- Euler form.
III	General equation of second degree, System of conics, Tracing of conics, Confocal conics, Polar equation of conics and its properties. Three-Dimensional Coordinates, Projection and Direction Cosine, Plane (Cartesian and vector form), Straight line in three dimension.
IV	Sphere, Cone and Cylinder. Central conicoids.

References:

1. Stephen H. Friedberg, A.J Insel & L.E. Spence, Linear Algebra, Person.
2. B. Rai, D.P. Choudhary & H. J. Freedman, A Course in Differential Equations, Narosa.
3. D.A. Murray, Introductory Course in Differential Equations, Orient Longman.
4. R.J.T. Bill, Elementary Treatise on Coordinate Geometry of Three Dimensions, McMillan India Ltd., 1994.
5. Robert J.T Bell, Elementary Treatise on Coordinate Geometry of three dimensions, Macmillan India Ltd.
6. S. Narayan & P.K. Mittal, Analytical Solid Geometry, S. Chand.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	III	
Course Code	B030301T	
Course Title	ALGEBRA & MATHEMATICAL METHODS	
Credit	6	Maximum Marks : 100

Course Objective:

1. Students will learn concepts of Group theory and Ring theory.
2. Students will understand relation between different types of groups and Rings.
3. Students will understand concepts related to functions of two variables, Fourier series and Fourier transforms, Laplace transforms and calculus of variations and their use in solving mathematical problems.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Appreciate the idea of Group and Ring theory and compare different types of Groups and Rings.
2. Apply results obtained for these algebraic structures in solving mathematical problems.
3. Compare Theorems related to functions of single variable and two variables and use these results.
4. Explain the importance of Fourier expansion of functions and use them.
5. Apply Laplace Transforms and Fourier transforms in solving differential equations.
6. Formulate real world problems as mathematical models and solve them using calculus of variation.

Syllabus

Unit	Course Content
I	Equivalence relations and partitions, Congruence modulo n, Definition of a group with examples and simple properties, Subgroups, Generators of a group, Cyclic groups. Permutation groups, Even and odd permutations, The alternating group, Cayley's theorem, Direct products, Coset decomposition, Lagrange's theorem and its consequences, Fermat and Euler theorems.
II	Normal subgroups, Quotient groups, Homomorphism and isomorphism, Fundamental theorem of homomorphism, Theorems on isomorphism. Rings, Subrings, Integral domains and fields, Characteristic of a ring, Ideal and quotient rings, Ring homomorphism.

III	Limit and Continuity of functions of two variables, Differentiation of function of two variables, Necessary and sufficient condition for differentiability of functions two variables, Young theorem, Taylor's theorem for functions of two variables with examples, Maxima and minima for functions of two variables, Jacobians. Existence theorems for Laplace transforms, Linearity of Laplace transform and their properties, Laplace transform of the derivatives and integrals of a function, Convolution theorem, inverse Laplace transforms, Solution of the differential equations using Laplace transforms.
IV	Fourier series, Fourier expansion of piecewise monotonic functions, Half and full range expansions, Fourier transforms (finite and infinite), Fourier integral. Calculus of variations-Variational problems with fixed boundaries-Euler's equation for functionals containing first order derivative and one independent variable, Extremals, Functionals dependent on higher order derivatives.

References:

1. J.B. Fraleigh, A first course in Abstract Algebra, Addison-weley
2. I. N. Herstein, Topics in Algebra, John Wiley & Sons.
3. T.M. Apostal, Mathematical Analysis, Person.
4. G.F. Simmons, Differential Equations with Application and Historical Notes, Tata -McGrawHill.
5. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	IV	
Course Code	B030401T	
Course Title	DIFFERENTIAL EQUATIONS & MECHANICS	
Credit	6	Maximum Marks : 100

Course Objective:

1. Students will learn about ordinary and partial differential equations and methods to model problems as problems related differential equations and to solve them.
2. Students will understand concepts related to mechanics like simple harmonic motions, motion under gravity, planetary motion etc.
3. Students will be equipped with tools related to differential equations and mechanics to pursue advanced studies and research in these fields.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain about origin and importance of differential equations.
2. Appreciate the role of some special functions like Bessel function and Legendre function in mathematics.
3. Describe different types of motions and effect of forces on a body.
4. Formulate problems in mathematical form solve them using differential equations.
5. Apply results studied related to mechanics in problems related to motion and forces.

Syllabus

Unit	**Course Content**
I	Second order linear differential equations with variable coefficients: Use of a known solution to find another, normal form, method of undetermined coefficient, variation of parameters, Series solutions of differential equations, Power series method. Bessel and Legendre functions and their properties, recurrence and generating relations.
II	Origin of first order partial differential equations. Partial differential equations of the first order and degree one, Lagrange's solution, Partial differential equation of first order and degree greater than one. Charpit's method of solution. Origin of second order PDE, Solution of partial differential equations of the second and higher order with constant coefficients, Classification of linear partial differential equations of second order.

III	Frame of reference, work energy principle, Forces in three dimensions, Poinsot's central axis, Wrenches, Null lines and planes. Virtual work, Catenary, Catenary of uniform strength.
IV	Velocities and accelerations along radial and transverse directions, and along tangential and normal directions, Simple Harmonic motion, Motion in resisting medium, Constrained motion. Central orbit, Kepler's laws of motion, Motion of particle in three dimensions, Acceleration in terms of different coordinates systems.

References:

1. G.F. Simmons, Differential Equations with Application and Historical Notes, Tata –McGrawHill.
2. B. Rai, D.P. Choudhary & H. J. Freedman, A Course of Ordinary Differential Equations, Narosa.
3. Ian N. Snedden, Elements of Partial Differential Equations, Dover Publication
4. A. Nelson, Engineering Mechanics Statics and Dynamics, Tata McGraw Hill.
5. J.L. Synge & B.A. Griffith, Principles of Mechanics, Tata McGraw Hill.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	V	
Course Code	B030501T	
Course Title	GROUP AND RING THEORY & LINEAR ALGEBRA	
Credit	5	Maximum Marks : 100

Course Objective:

1. Students will learn about concepts related to Groups, Rings.
2. Students will learn the concepts of integral domains and the generalization of the idea of divisibility, primes etc.
3. Students will understand the branch of linear algebra and learn to apply the results obtained in solving problems related to mathematics and other fields.
4. Students will be equipped with knowledge on topics related to algebra and linear algebra which will enable them to do advanced studies in these fields and interdisciplinary areas.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain various concepts and theorems related to Group theory and Ring theory.
2. Interconnect and compare ideas like divisibility and primes studied in this course with what they are familiar in relation to natural numbers.
3. Explain various results related to Linear algebra.
4. Appreciate the role of Basis in vector spaces, and relation of linear transformations with matrices.
5. Apply the concepts studied in this course in solving real world problems.

Syllabus

Unit	**Course Content**
I	Automorphism, inner automorphism, Automorphism groups, Automorphism groups of finite and infinite cyclic groups, Characteristic subgroups. Conjugacy classes, The class equation, Finite simple groups, Nonsimplicity tests; Generalized Cayley's theorem, Index theorem, Embedding theorem and applications.
II	Polynomial rings over commutative rings, Division algorithm and consequences, Principal ideal domains, Factorization of polynomials. Divisibility in integral domains, Irreducibles, Primes, Unique factorization domains, Euclidean domains.

III	Vector spaces, Subspaces, Linear independence and dependence of vectors, Basis and Dimension, Quotient space. Linear transformations, The Algebra of linear transformations, rank nullity theorem, their representation as matrices.
IV	Linear functionals, Dual space, Characteristic values, Cayley Hamilton Theorem. Inner product spaces and norms, Cauchy-Schwarz inequality, Orthogonal vectors, Bilinear and Quadratic forms.

References:

1. Topics in Algebra by I. N. Herstein.
2. Linear Algebra by K. Hoffman and R. Kunze.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	V	
Course Code	B030502(A)T	
Course Title	NUMBER THEORY & GAME THEORY	
Credit	5	Maximum Marks : 100

Course Objective:

1. Students will learn about concepts related to number theory and how to apply them.
2. Students will learn about game theory and how it can be applied in decision making in strategic situations.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Describe concepts related to number theory like divisibility, congruences, primes, generating functions etc.
2. Apply results related to number theory in solving problems.
3. Appreciate the role of game theory in decision making.
4. Use results of game theory in solving strategic problems involving decision making.

Syllabus

Unit	**Course Content**
I	**Theory of numbers:** 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. **Congruences:** Congruence modulo powers of prime; primitive roots and their existence; quadratic residues; Legendre symbol, Gauss' lemma about Legendre symbol; quadratic reciprocity law; proofs of various formulations; Jacobi symbol.
II	**Diophantine Equations:** Solutions of ax + by = c, $x^n + y^n = z^n$; properties of Pythagorean triples; sums of two, four and five squares; assorted examples of Diophantine equations. **Generating Functions and Recurrence Relations:** Generating Function Models, Calculating coefficient of generating functions, Partitions, Exponential Generating Functions, A Summation Method. Recurrence Relations: Recurrence Relation Models, Divide and conquer Relations, Solution of Linear, Recurrence Relations,

	Solution of Inhomogeneous Recurrence Relations, Solutions with Generating Functions.
III	Introduction, overview, uses of game theory, some applications and examples, and formal definitions of: the normal form, payoffs, strategies, pure strategy Nash equilibrium. Introduction, characteristic of game theory, Two- person zero-sum game, Pure and Mixed strategies, Saddle point and its existence.
IV	Fundamental Theorem of Rectangular games, Concept of Dominance, Dominance and Graphical method of solving Rectangular games. Relationship between rectangular game and Linear Programming Problem, Solving rectangular game by Simplex method, reduction of m x n game and solution of 2x2, 2 x s, and r x 2 cases by graphical method, algebraic and linear programming solution of m x n games.

References:

1. Burton, D. M. (2002) Elementary Number Theory (4th edition) Universal Book Stall, New Delhi.
2. Niven, I., Zuckerman, H. S. and Montegomery, H. L. (2003) An Int. to the Theory of Numbers (6th edition) John Wiley and sons, Inc., New York.
3. Balakrishnan,V. K. (1996) Introductory Discrete Mathematics, Dover Publications.
4. Martin Osborne, An Introduction to Game Theory, Oxford University Press, 2003.
5. Vijay Krishna, Game Theory, Academic Press.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	V	
Course Code	B030502(B)T	
Course Title	GRAPH THEORY & DISCRETE MATHEMATICS	
Credit	5	Maximum Marks : 100

Course Objective:

1. Students will learn about various types of graphs, their terminology and applications.
2. Students will learn about using logic to prove statements and learn about discrete structures including Boolean algebra and their applications.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Describe various concepts like graphs, isomorphisms of graph, their colouring etc.
2. Appreciate and apply the results related to graphs to real world problems.
3. Explain concepts like truth tables, Boolean algebra etc. related to discrete mathematics.
4. Apply these concepts in real world problems specially in computer science.

Syllabus

Unit	**Course Content**
I	Introduction to graphs, basic properties of graphs, Simple graph, multi graph, graph terminology, representation of graphs, Bipartite, regular, planar and connected graphs, connected components in a graph, Euler graphs, Directed, Undirected, multi-graph, mixed graph. Walk and unilateral components, unicursal graph, Hamiltonian path and circuits, Graph colouring, chromatics number, isomorphism and homomorphism of graphs, Incidence relation and degree of the graph.
II	Operation of graph circuit, Path and circuits, Eulerian circuits, Hamiltonian path and cycles, Adjacency matrix, Weighted graph, Travelling salesman problem, Shortest path, Dijkstra's algorithm. Tree, Binary and Spanning trees, Coloring, Color problems, Vertex coloring and important properties.
III	**Propositional Logic-** Proposition logic, basic logic, logical connectives, truth tables, tautologies, contradiction, normal forms(conjunctive and disjunctive), modus ponens and modus tollens, validity, predicate logic, universal and existential quantification, proof by implication, converse, inverse contrapositive, contradiction, direct proof

	by using truth table. **Relation-** Definition, types of relation, domain and range of a relation, pictorial representation of relation, properties of relation, partial ordering relation. **Boolean Algebra-** Basic definitions, Sum of products and products of sums, Logic gates and Karnaugh maps.
IV	**Combinatories-** Inclusion- exclusion, recurrence relations (nth order recurrence relation with constant coefficients, Homogeneous recurrence relations, Inhomogeneous recurrence relations), generating function (closed form expression, properties of G.F., solution of recurrence relations using G.F. solution of combinatorial problem using G.F.) **Finite Automata-** Basic concepts of automation theory, Deterministic Finite Automation (DFA), transition function, transition table, Non Deterministic Finite Automata (NDFA), Mealy and Moore machine, Minimization of finite automation.

References:

1. "Graph Theory with Applications to Engineering and Computer Science" by Narsingh Deo.
2. Introduction to Graph Theory" by Douglas B West,
3. Graph Theory with Algorithms and Its Applications: In Applied Science and Technology" by Santanu Saha Ray
4. Discrete Mathematics by C. L.Liu..
5. Discrete Mathematics with computer application by Trembley and Manohar.
6. Discrete Mathematics and Its Applications by Kenneth H. Rosen.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	V	
Course Code	B030502(C)T	
Course Title	DIFFERENTIAL GEOMETRY & TENSOR ANALYSIS	
Credit	5	Maximum Marks : 100

Course Objective:

1. Students will learn about theory of curves, surfaces, geodesics etc.
2. Students will get familiarized with different types of tensors and their role in geometry.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain properties of curves, surfaces, geodesics, metrics etc.
2. Will be able to differentiate between different types of tensors and their roles.
3. Apply results related tensors in solving problems in geometry.
4. Appreciate the role of Riemannian space and Einstein space.

Syllabus

Unit	Course Content
I	Local theory of curves-Space curves, Examples, Plane Curves, tangent and normal and binormal, Osculating Plane, normal plane and rectifying plane, Osculating circle, osculating sphere Helices, Serret-Frenet apparatus, contact between curve and surfaces, tangent surfaces, involutes and evolutes of curves, Bertrand curves, Intrinsic equations, fundamental existence theorem for space curves. Local Theory of Surfaces- Parametric patches on surface curve of a surface, family of surfaces (one parameter), edge of regression, rues surfaces, skew ruled surfaces and developable surfaces, surfaces of revolution.
II	Metric-first fundamental form and arc length, Direction coefficients, families of curves, intrinsic properties, geodesics, canonical geodesic equations, normal properties of geodesics, geodesics curvature, Geodesic polars. Gauss-Bonnet theorem, curvature of curves on surfaces, Gaussian curvature, normal curvature, Meusneir's theorem, mean curvature, Gaussian curvature, umbilic points, lines of curvature, Rodrigue's formula, Euler's theorem.

III	Tensor algebra: Vector spaces, the dual spaces, tensor product of vector spaces, transformation formulae, contraction, special tensors- symmetric tensor, inner product, associated tensor with examples. Tensor Analysis: Contravariant and covariant vectors and tensors, Mixed tensors, Symmetric and skew-symmetric tensors, Algebra of tensors, Contraction and inner product, Quotient theorem, Reciprocal tensors, Christoffel's symbols, Law of transformation of Christoffel's symbols, Covariant differentiation, non- commutativity of Covariant derivative.
IV	Gradient of scalars, Divergence of a contravariant vector, covariant vector and conservative vectors, Laplacian of an invariant, curl of a covariant vector, irrotational vector, with examples. Riemannian space, Riemannian curvatures and their properties, geodesics, geodesic curvature, geometrical interpretation of curvature tensor, Ricci tensor, scalar curvature, Einstein space and Einstein tensor.

References:

1. T.J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
2. B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
3. B. Spain, Tensor Calculus: A Concise Course, Dover Publications, 2003.
4. Tensors- Mathematics of Differential Geometry by Z. Ahsan, PHI,2015
5. David C. Kay, Tensor Analysis, Schaum's Outline Series, McGraw Hill 1988.
6. R. S, Mishra, A Course in Tensors with Applications to Reimannian Geometry, Pothishala Pvt. Ltd, Allahabad.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	VI	
Course Code	B030601T	
Course Title	METRIC SPACES & COMPLEX ANALYSIS	
Credit	5	Maximum Marks : 100

Course Objective:

1. Students will learn about metric spaces which are endowed with a metric which is generalized form of the concept of distance.
2. Students will learn basic concepts related to complex numbers and functions defined on them.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain concepts related to metric spaces.
2. Compare the idea of distance with the idea of metric.
3. Describe results related to complex analysis.
4. Appreciate the similarities and contrast between the results related to real analysis and complex analysis.
5. use the concepts studied in this course in advanced level studies.

Syllabus

Unit	**Course Content**
I	Metric spaces: Definition and examples, Sequences in metric spaces, Cauchy sequences, Complete metric space. Open and closed ball, Neighborhood, Open set, Interior of a set, limit point of a set, derived set, closed set, closure of a set, diameter of a set, Cantor's theorem, Subspaces, Dense set. Continuous mappings.
II	Functions of complex variable, Mappings; Mappings by the exponential function, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulae, Cauchy-Riemann equations, sufficient conditions for differentiability, analytic functions and their examples.
III	Exponential function, Logarithmic function, Trigonometric function, Derivatives of functions. Linear and bilinear transformations, Fixed points, cross ratio, inverse points and critical points.
IV	Definite integrals of functions, Contours, Contour integrals and its examples. Cauchy integral formula; an extension of Cauchy integral formula, consequences of Cauchy integral formula, Liouville,s theorem

	and fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples; Laurent series and its examples, Absolute and uniform convergence of power series. Types of singular points, residues at poles and its examples.

References:

1. Mathematical Analysis by Shanti Narain.
2. Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.
3. Simmons, G. F. (2004). Introduction to Topology and Modern Analysis.Tata McGraw Hill. New Delhi.
4. Function of Complex Variable by Shanti Narain.
5. Complex variable and applications by Brown & Churchill.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	VI	
Course Code	B030602T	
Course Title	Numerical Analysis & Operations Research	
Credit	5	Maximum Marks : 100

Course Objective:

1. Students will learn use of numerical analysis in differentiation, integration, solving equations, polynomial approximations, difference equations etc.
2. Students will understand concepts related to operations research and their applications.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Describe various techniques of numerical analysis.
2. Apply numerical methods to solve equations, find derivatives and integral of functions, approximate functions, solve differential equations and difference equations.
3. Explain concepts related to operations research.
4. Use techniques of linear programming, assignment problems and transportation problems to solve problems related to operations research.

Syllabus

Unit	**Course Content**
I	Solution of equations: bisection, Secant, Regular Falsi, Newton Raphson's method, Newton's method for multiple roots, Interpolation, Lagrange and Hermite interpolation, Difference schemes, Divided differences, Interpolation formula using differences. Numerical differentiation, Numerical Quadrature: Newton Cotes Formulas, Gaussian Quadrature Formulas, System of Linear equations: Direct method for solving systems of linear equations (Gauss elimination, LU Decomposition, Cholesky Decomposition), Iterative methods (Jacobi, Gauss Seidel, Relaxation methods). The Algebraic Eigen value problem: Jacobi's method, Givens method, Power method.
II	Numerical solution of Ordinary differential equations: Euler method, single step methods, Runge-Kutta method, Multi-step methods: Milne-Simpson method, Types of approximation: Last Square polynomial approximation, Uniform approximation, Chebyshev polynomial approximation. Difference Equations and their solutions, Shooting method and Difference equation method for solving Linear second order differential

	equation with boundary conditions of first, second and third type.
III	Introduction, Linear programming problems, statement and formation of general linear programming problems, graphical method, slack and surplus variables, standard and matrix forms of linear programming problem, basic feasible solution. Convex sets, fundamental theorem of linear programming, basic solution, Simplex method, introduction to artificial variables, two phase method Big-M method and their comparison.
IV	Resolution of degeneracy, duality in linear programming problems, primal dual relationships, revised simplex method, sensitivity analysis. Transportation problems, assignment problems.

References:

1. Numerical Methods for Engineering and scientific computation by M. K. Jain, S.R.K. Iyengar and R.K. Jain.
2. Introductory methods of Numerical Analysis by S. S. Sastry.
3. Sharma, J.K(2017). "Operations Research- An Introduction", Laxmi publications, 6th edition.
4. Taha, Hamdy H, "Operations Research- An Introduction ", Pearson Education.
5. Kanti Swarup, P. K. Gupta, Man Mohan Operations research, Sultan Chand & Sons.
6. Hillier Frederick S and Lieberman Gerald J., "Operations Research", McGraw Hill Publication.

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(A State University established under the Uttar Pradesh University Act 1973)

Syllabus
(B.A./B.Sc. Mathematics)

Semester	VII	
Course Code	B030701T	
Course Title	Algebra-I	
Credit	5	Maximum Marks : 100

Course Objective: students will learn concepts related to advanced algebra and how to apply them in solving mathematical problems.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain various concepts related to algebra.
2. Apply results in problems arising in higher mathematics.
3. Characterize different types of groups.

Syllabus

Unit	**Course Content**
I	Action of a group G on a set S, Equivalent formulation as a homomorphism of G to T(S), Examples, Stabilizer (Isotropy) subgroups and Orbit decomposition, Class equation of an action, Its particular cases (left multiplication and conjugation), Conjugacy class equation, Core of a subgroup.Sylow's Theorem I, II and III.
II	Subnormal and normal series, Zassenhaus's lemma (Statement only)Schreier's rèfinement theorem, composition series, Jordan – Holder theorem, Chain conditions, Examples, Internal and External direct products and their relationship, Indecomposability. p–groups, Examples and applications, Groups of order pq.
III	Commutators, Solvable groups, Solvability of subgroups, factor groups and of finite p – groups, Examples, Lower and upper central series, Nilpotent groups and their equivalent characterizations.
IV	Factorization theory in commutative domains, Prime and irreducible elements, G.C.D., Euclidean domains, Maximal and prime ideals, Principal ideal domains, Unique factorization domains, Examples and counter examples, Chinese remainder theorem for rings and PID's, Polynomial rings over domains, Eisenstein's irreducibility criterion, Unique factorization in polynomial rings over UFD's.

References:

1. Dummit,D.S. and Foote, R. M.(2003). *Abstract Algebra.*John Wiley, N.Y.
2. Gopalakrishnan, N.S.(2015).*University Algebra* (3rd ed.).New Age Int. Pub.
3. Jacobson, N.(1984). *Basic Algebra*(Vol. 1). Hindustan Publishing Co, New Delhi.
4. Lal, R.(2002). *Algebra*(Vols. I & II). Shail Publications, Allahabad.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	VII	
Course Code	B030702T	
Course Title	Real Analysis	
Credit	5	Maximum Marks : 100

Course Objective: students will learn about concepts related to real analysis such as R-S integration, convergence of sequence and series of functions and multivariable calculus and their applications in mathematics and science.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain concepts like R-S integration, convergence of sequence of functions, multivariable calculus etc.
2. Solve problems real analysis in Mathematics and Sciences.
3. Compare different types of integrations.
4. Do research using knowledge gained in this course.

Syllabus

Unit	Course Content
I	Definition and existence of Riemann – Stieltjes integral, Conditions for R–S integrability. Properties of the R-S integral, R-S integrability of functions of a function Integration and differentiation, Fundamental theorem of Calculus.
II	Series of arbitrary terms. Convergence, divergence and oscillation, Absolute Convergence, Abel's and Dirichilet's tests. Multiplication of series. Rearrangements of terms of a series, Riemann's theorem and sum of series, Sequences and series of functions.
III	Pointwise and uniform convergence, Cauchy's criterion for uniform convergence, uniform convergence and continuity, uniform convergence and Riemann-Stieltjies integration, Uniform convergence and differentiation, Weierstrass approximation theorem, Power series. Uniqueness theorem for power series, Abel's and Tauber's theorems.
IV	Functions of Several Variables, Linear transformations, Derivatives in an open subset of R^n Jacobian matrix and Jacobians, Chain rule and its matrix form, Interchange of order of differentiation, Derivatives of higher orders Taylor's theorem, Inverse function theorem, Implicit function theorem, Extremum problems with constraints, Lagranges multiplier method.

References:

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1- Rudin, W.(1976). *Principle of Mathematical Analysis*(2nd ed.). McGraw-Hill Kogakusha, International Student Edition.
2- Apostol, T. M.(1985). *MathematicalAnalysis*. Narosa Publishing House, New Delhi.
3- Lang, S. (1969). *Analysis I and II*. Addision-Wesley Pub. Co.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	VII	
Course Code	B030703T	
Course Title	BASIC TOPOLOGY	
Credit	5	Maximum Marks : 100

Course Objective: students will learn about concepts related to metric spaces and topological spaces and how different types of topological spaces have different properties.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain various concepts related to Metric Space and Topology.
2. Characterize different types of Topological spaces.
3. Solve problems requiring knowledge of Topology.

Syllabus

Unit	**Course Content**
I	Metric spaces: Continuity of functions, Properties of continuous functions, Homeomorphisms. Connectedness in metric spaces, Connected sets in the real line, Continuity and connectedness, Compactness, closed subset of a compact space, compact subset of a metric space, Continuity and compactness.
II	Definition and examples of topological spaces. Closed sets. Closure. Dense sets. Neighborhoods, interior, exterior, and boundary. Accumulation points and derived sets. Bases and sub-bases. Subspaces and relative topology.
III	Alternative methods of defining a topology in terms of Kuratowski closure operator and neighborhood systems. Continuous functions and homeomorphism. First and second countable spaces. Lindelof spaces. Separable spaces. Nets and filters.
IV	The separation axioms $T_0, T_1, T_2, T_3, T_{3\frac{1}{2}}, T_4$; their characterizations and basic properties. Urysohn's lemma, Tietze extension theorem. Metric topology and metrization.

References:

1. Kelley, J. L.(1995). *General Topology*. Van Nostrand.
2.Joshi, K. D.(1983). *Introduction to General Topology*. Wiley Eastern.
3.Munkres, J. R.(2000).*Topology*(2nd ed.). Pearson Internationl.
4.Dugundji, J. (1966). *Topology*. Prentice-Hall of India.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	VII	
Course Code	B030704T	
Course Title	COMPLEX ANALYSIS	
Credit	5	Maximum Marks : 100

Course Objective: students will learn various concepts related to complex analysis and their application in mathematics and science.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain various concepts related to complex analysis.
2. Apply results studied in problems arising in physical sciences.
3. Relate different theorems.
4. Develop new theories and do research in higher mathematics.

Syllabus

Unit	**Course Content**
I	Analytic continuation, uniqueness of analytic continuation, Natural Boundary, complete analytic functions , Power series method ofAnalytic continuation, Schwarz's Lemma, Inverse function theorem, Schwarz's reflection principle, Reflection across analytic arcs.
II	Residue at infinity, Cauchy's Residue theorem, Contour integration: Integral of the type $\int_{\alpha}^{2\pi+\alpha} f(cos\theta, sin\theta)d\theta, \int_{-\infty}^{\infty} f(x)dx, \int_{-\infty}^{\infty} g(x)cosmx\, dx$. Singularities on the real axis, Integrals involving branch points, Jordan's Lemma.
III	The Riemann mapping theorem, Behavior at the boundary, Picard' theorem, Borel theorem, Infinite Products, Jensen's formula, Poission – Jenson formula, Borel Cartheodory theorem.
IV	Entire Functions with Rational Values, The Phragmen-Lindelof and Hadamard Theorems, Meromorphic Functions, Mittag-Leffler Theorem,Weierstrass factorization theorem, Gama functions.

References:

1. Lang, S.(1999).*Complex Analysis* (4th ed.). Springer.
2.Bak, J. and Newman, D. J.(2010).*Complex Analysis* (3rd ed.). Springer.
3. Conway, J. B.(1980).*Functions of One Complex Variable*(2nd ed.).Narosa Pub. House.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	VIII	
Course Code	B030801T	
Course Title	ALGEBRA-II	
Credit	5	Maximum Marks : 100

Course Objective: students will learn about algebraic concepts related to module theory and field theory and their applications.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Describe properties of Modules and Fields.
2. Differentiate different types of Modules.
3. Use these results in advanced level mathematical studies.

Syllabus

Unit	**Course Content**
I	Modules over a ring. Endomorphism ring of an abelian group. R-Module structure on an abelian group M as a ring homomorphism form R to End M, Submodules, Direct summands, Homomorphism, Factor modules, Correspondence theorem, Isomorphism theorems, Exact sequences, Five lemma.
II	Free modules, Homomorphism extension property, Equivalent characterization as a direct sum of copies of the underlying ring, Split exact sequences and their characterizations, Left exactness of Hom sequences and counter-examples for non-right exactness, Projective modules, Injective modules.
III	Noetherian modules and rings, Equivalent characterizations, Submodules and factors of noetherian modules, Characteristic of a field, Prime subfields, Field extension, Finite extensions, Algebraic and transcendental extensions. Factorization of polynomials in extension fields, Splitting fields and their uniqueness.
IV	Separable field extensions, Perfect fields, Separability over fields of prime characteristic, Transitivity of separability, Automorphisms of fields, Dedekind's theorem, Fixed fields, Normal extensions, Splitting fields and normality, Normal closures.

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References:

1.Dummit, D. S. and Foote,R. M.(2003).*Abstract Algebra*. John Wiley, N.Y.

2. Anderson F. W. and Fuller, K. R.(1974). *Rings and Categories of Modules*, Springer, N.Y.

3. Adamson, I. A.(1964).*An Introduction to Field Theory*. Oliver & Boyd, Edinburgh.

4. Gopalakrishnan, N. S. (2015). *University Algebra* (3rd ed.).New Age Int. Pub.

5. Hungerford, T. W.(2004). *Algebra*. Springer (India) Pvt. Ltd.

6. Lal, R. (2002).*Algebra* (Vol. 2.). Shail Publishing House, Allahabad.

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Syllabus

Semester	VIII	
Course Code	B030802T	
Course Title	FUNCTIONAL ANALYSIS-I	
Credit	5	Maximum Marks : 100

Course Objective: students will learn about normed linear spaces, their properties and types and functions on them.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Give examples of Normed linear spaces.
2. Differentiate between different types of normed linear spaces.
3. Use the results in problems arising in Functional Analysis and other branches of mathematics.

Syllabus

Unit	Course Content
I	Normed linear spaces, Banach spaces, their examples including $\mathbb{R}^n$, $\mathbb{C}^n$,l_p^n , l_p, C[a,b] and topological properties, Holder's and Minkowski's inqualities, Subspaces, Quotient space of a normed linear space and its completeness.
II	Continuous linear transformations, Spaces of bounded transformations, Continuous linear functional, Hahn Banach theorems(separation and extension), strict convexity and uniqueness of Hahn Banach extension , Banach Steinhous theorem, Uniform boundedness principle.
III	Open mapping theorem, Bounded inverse theorem, Projection,Closed graph theorem, Finite dimensional normed linear spaces, Compactness, Equivalent norms, Bolzano Weistrass property.
IV	Duals of $\mathbb{R}^n$, $\mathbb{C}^n$,l_p^n, l_p, C[a,b], weak and weak* convergence, Embedding and reflexivity, Uniform convexity and Milman theorem.

References:

1. Simmons, G. F. (1963). *Introduction to Topology and Modern Analysis*. McGraw Hill.
2. Ponnusamy, S. (2002). *Foundation of Functional Analysis*. Narosa Publishing House.
3. Limaye, B. V.(2017).*Functional Analysis*(3rd ed.). New Age Int. Publisher.

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Syllabus
(B.A./B.Sc. Mathematics)

Semester	VIII	
Course Code	B030803T	
Course Title	Measure & Integration-I	
Credit	5	Maximum Marks : 100

Course Objective: students will learn concepts related to Lebesgue measure and Lebesgue integration and their applications.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Compare different types of integration.
2. Select the appropriate results to use them in solving problems.
3. Use the results in Mathematical research.

Syllabus

Unit	**Course Content**
I	Lebesgue outer and inner measure, Lebesgue measure on R, translation invariance of Lebesgue measure, existence of a non-measuable set, characterizations of Lebesgue measurable sets, Borel sets, Cantor-Lebesgure function.
II	Measurable functions on a measure space and their properties, Borel measurable functions, simple functions and their integrals, Lebesgue integral on R and its properties, Riemann and Lebesgue integrals.
III	Integral of non negative measureable function and of unbounded functions,Bounded convergence theorem, Fatou's lemma, Monotone convergence theorem, Lebesgue dominated convergence theorem.
IV	The L^p-space. Convex functions. Jensen's inequality, Holder and Minkowski inequalities, Completeness of L^p, Convergence in measure, Almost uniform convergence.

References:

1. Royden, H.L. and Fitzpatrick, P.M.(2015).*Real Analysis*(4th ed.). Pearson.
2. Halmos, P.R.(1994). *Measure Theory*. Springer.
3. Rana, I.K.(2005). *An Introduction to Measure and Integration* (2nd ed.).Narosa Publishing House.
4. Hewit, E. and Stromberg,K.(1975). *Real and Abstract Analysis*. Springer.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	VIII	
Course Code	B030804(A)T	
Course Title	CLASSICAL MECHANICS	
Credit	5	Maximum Marks : 100
Course Objective: students will learn concepts related to Classical Mechanics and their application in solving problems related to physical sciences.		
Learning Outcomes: After successful completion of the syllabus, learners will be able to: 1. Describe concepts related to mechanics. 2. Apply the results in solving problems in physical sciences. 3. Create new theories related to mechanics.		

Syllabus	
Unit	**Course Content**
I	The linear momentum and the angular momentum of a rigid body in terms of inertia constants, kinetic energy of a rigid body, equations of motion, examples on the motion of a sphere on horizontal and on inclined planes. Euler's equations of motion, motion under no forces, Eulerian angles and the geometrical equations of Euler.
II	Generalized co-ordinates, holonomic and non-holonomic systems, configuration space, Lagrange's equations using D'Alembert's Principle for a holonomic conservative system, deduction of equation of energy when the geometrical equations do not contain time explicitly, Lagrange's multipliers case, deduction of Euler's dynamical equations from Lagrange's equations.
III	Theory of small oscillations, Lagrange's method, normal (principal) co-ordinates and the normal modes of oscillation, small oscillations under holonomic constraints,stationary property of normal modes, Lagrange equations for impulsive motion.
IV	Generalized momentum and the Hamiltonian for a dynamical system, Hamilton's canonical equations of motion, Hamiltonian as a sum of kinetic and potential energies, phase space and Hamilton's Variational principle, the principle of least action, canonical transformations, Hamilton-Jacobi theory, Integrals of Hamilton's equations and Poisson-Brackets, Poisson- Jacobi identity.

References:

1. Ramsey, A. S. (1985). *Dynamics*: *Part II.* CBS Publishers & Distributors.

2. Goldstein, H. (1969). *Classical Mechanics*. Addison-Wesley Publishing Company.

3. Rana, K. C. and Joag, P. C.(1991) *Classical Mechanics*. Tata McGraw- Hill.

Syllabus
(B.A./B.Sc. Mathematics)

Semester	VIII	
Course Code	B030804(B)T	
Course Title	SPECIAL THEORY OF RELATIVITY	
Credit	5	Maximum Marks : 100

Course Objective: students will learn concepts related to special theory of relativity and their applications.

Learning Outcomes: After successful completion of the syllabus, learners will be able to:

1. Explain concepts related to Special Theory of Relativity.
2. Compare Newtonian Mechanics and Relativistic Mechanics.
3. Apply the results to solve problems related to relativity.

Syllabus

Unit	**Course Content**
I	Review of Newtonian Mechanics, Inertial frame, Speed of light and Galilean relativity, Michelson-Morley experiment, Lorentz-Fitzerold contraction hypothesis, relative character of space and time, postulates of special theory of relativity, Lorentz transformation equations and geometrical interpretation, Group properties of Lorentz transformations.
II	Relativistic kinematics, composition of parallel velocities, length contraction, time dilation, transformation equations, equations for components of velocity and acceleration of a particle and contraction factor.
III	Geometrical representation of space time, four dimensional Minkowskian space of special relativity, time-like intervals, light-like and space-like intervals, Null cone, proper time, world line of a particle, four vectors and tensors in Minkowskian space time.
IV	Relativistic mechanics-Variations of mass with velocity, equivalence of mass energy, transformation equation for mass, momentum and energy, Energy momentum for light vector, relativistic force and transformation equation for its components, relativistic Lagrangian and Hamiltonian, relativistic equations of motion of a particle, energy momentum tensor of a continuous material distribution.

References:

1. Mollar, C.(1952). *Theory of relativity*, Clarendon press.
2.Resnick, R. (1972).*Introduction to special relativity*. Wiley Eastern Pvt. Ltd.
3.Anderson, J. L.(1967). *Principles of relativity*, Academic Press.