DEPARTMENT OF MATHEMATICS & ASTRONOMY

UNIVERSITY OF LUCKNOW

PROPOSED YEAR WISE STRUCTURE & SYLLABUS OF FOUR YEAR U.G. PROGRAM IN MATHEMATICS

UNDER

NATIONAL EDUCATION POLICY 2020

UG - Mathematics Programme

Programme Outcomes

Certificate in Applied Mathematics

1. Ability to communicate mathematical ideas clearly using correct mathematical terminology and proper mathematical notation and use their mathematical knowledge to solve problems.
2. Develop appreciation and competency for application of mathematical approaches and techniques to variety of problems and applications to problems in other disciplines such as engineering, business and other decisional sciences.

Diploma in Mathematics

3. Prepare sound mathematical base for enhancing understanding in interdisciplinary subjects such as physics, engineering, computer science etc. and for pursuing Master's Degree in Mathematics or Engineering/Computer science/ Business/Economics

Degree in Mathematics

4. Utilize mathematical skills to coach school and college students or enhance their own career prospects through pursuit of advanced degree in mathematics or full-fill prerequisites of eligibility for various national and international competitive examinations.

B.Sc. Research

5. Comprehend, analyse and apply knowledge gained to formulate research objectives, adopt appropriate methodology in identified research area to provide plausible mathematical solutions in chosen research project.

6. Build solid foundation to pursue Masters degree in Mathematics with research orientation as a prerequisite for Ph.D. in Mathematics.

Programme Specific Outcomes

1. To formulate, analyze, and solve problems through application of fundamental mathematical techniques
2. To develop the ability to determine the validity of a given argument, develop mathematical thinking and be able to solve mathematical problems and construct mathematical proofs independently.
3. To demonstrate an understanding of the foundations of various branches of mathematics and apply the same to formulate and develop mathematical arguments in a logical manner.
4. Apply knowledge and mathematical skills to translate information presented into mathematical form, select and use appropriate mathematical formulae or techniques in order to process the information and draw the relevant conclusion.

5. Investigate and apply mathematical solutions in a variety of contexts related to science, technology, business and industry, and illustrate these solutions using symbolic, numeric, or graphical methods.
6. Build a solid foundation for higher studies in mathematics and other disciplines requiring quantitative techniques and enhancing their career prospects through success in competitive examinations for further academic progression or placement in various positions requiring mathematical or quantitative background as a pre-requisite.

	Proposed Structure UG- Mathematics											
Year	**Sem.**	**Major1**			**Major 2**		**Minor**		**CC/VC**		**Total**	**Award**
		Mathematics		**Credits**		**Credits**		**Credits**		**Credits**	**Credits**	
1	**Sem. 1**	P-1	Differential Calculus	4	P-1	4	P-1	4	**CC1**	4	24	**Certificate**
		P-2	Matrices and Algebra	4	P- 2	4						
	Sem. 2	P-3	Integral Calculus	4	P-3	4	P-2	4	**VC1**	4	24	
		P-4	Geometry	4	P-4	4						
2	**Sem.3**	P-5	Ordinary Differential Equations	4	P- 5	4	P-3	4	**CC2**	4	24	**Diploma**
		P-6	Mechanics	4	P-6	4						
	Sem. 4	P-7	Mathematical Methods	4	P-7	4	P-4	4	**VC2**	4	24	
		P-8	Linear & Abstract Algebra	4	P-8	4						
3	**Sem. 5**	P-9	Numerical Analysis	4	P-9	4			**Internship/ Term Assignment**	4	24	**Degree**
		P-10	Analysis	4	P-10	4						
		P- 11 A	Integral & Partial Differential Equations	4								
		P- 11 B	Discrete Mathematics									
		P- 11 C	Number Theory									
	Sem. 6	P-12	Advanced Algebra	4	P-11	4			**Minor Project**	4	24	
		P-13	Differential Geometry & Tensor Analysis	4	P-12	4						
		P-14 A	Advanced Differential Equations	4								
		P-14 B	Operations Research									
4	**Sem. 7**	P- 15	Topology	4					**Research Methodology**	4	24	**B.Sc. Research**
		P- 16	Fluid Mechanics	4								
		P- 17	Geometry of Manifolds	4								
		P-18	Complex Analysis	4								
		P-19 A	Module Theory	4								
		P- 19 B	Measure Theory & Integration									
	Sem. 8								**Major Project**	24	24	

UG Semester I

Paper 1: Differential Calculus

Credit: 4 T:04

Course Outcomes:

1. Know the concepts of calculus, namely, limits, continuity, differentiability of functions of one and two variables and their applications in the form of mean value theorem and Taylor's theorem.
2. Sketch curves in a plane using its mathematical properties in the different coordinate systems of reference.
3. Apply derivatives in Optimization, Social sciences, Physics and Life sciences etc.
4. Get knowledge of curvature, asymptotes, envelopes and evolutes.

UNIT I

Limit, continuity and differentiability of function of single variable, Cauchy's definition, Heine's definition, 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, indeterminate forms.

UNIT II

Rolle's theorem, Lagrange and Cauchy Mean value theorems, mean value theorems ofhigher order, Taylor's theorem with various forms of remainders, Successive differentiation, Leibnitz theorem, Maclaurin's and Taylor's series,

Limit and Continuity of functions of two variables, Differentiation of function of two variables, Necessary and sufficient condition for differentiability of functions two variables.

UNIT III

Partial differentiation, Euler's theorem on homogeneous function, Schwarz's and Young theorem, Taylor's theorem for functions of two variables with examples, Maxima and minima for functions of two variables, Lagrange multiplier method, Jacobians, Inverse function theorem and implicit function theorem.

UNIT IV

Tangents and normals, Asymptotes, Curvature, Envelops and evolutes, Tests forconcavity and convexity, Points of inflexion, Multiple points, Parametric representation of curves and tracing of parametric curves, Tracing of curves in Cartesian and Polar forms.

References:

Text Books:

1. T.M. Apostol, Calculus Vol. I, John Wiley & Sons Inc.
2. S. Balachandra Rao, C. K. Shantha, Differential Calculus, New Age Publication.

Suggested Reading:

3. H. Anton, I. Birens and S. Davis, Calculus, John Wiley and Sons, Inc.,2002.
4. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, 2007.

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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http://heecontent.upsdc.gov.in/SearchContent.aspx

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Paper 2: Matrices and Algebra

Credit: 4 T:04

Course Outcomes:

1. Find the rank and eigen values of matrices.
2. Study the system of linear homogeneous and non-homogeneous equations.
3. Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.
4. Link the fundamental concepts of Groups and symmetrical figures.
5. Analyze the subgroups of cyclic groups.
6. Explain the significance of the notion of cosets, normal subgroups, and factor group.
7. Understand the concepts of rings, subrings and fields.

UNIT I

Elementary operations on matrices, Rank of a matrix, Echelon and 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, Cayley-Hamilton theorem and its use in finding inverse of a matrix.

UNIT II

Equivalence relations and partitions, Congruence modulo n, Definition of a group with examples and simple properties, Subgroups, Generators of a group, Cyclic groups, Coset decomposition, Lagrange's theorem and its consequences, Fermat and Euler theorems. Normal subgroups, Quotient groups.

UNIT III

Homomorphism and isomorphism, Fundamental theorem of homomorphism, Theorems on isomorphism, Permutation groups, Even and odd permutations, The alternating group, Cayley's theorem, Direct products.

UNIT IV

Rings, types of rings (commutative rings, rings with unity, division rings, Integral domains and fields) with examples, basic properties, sub-rings, Characteristic of a ring, Ideals and quotient rings, Ring homomorphism, Isomorphism theorems, Field of quotient of an integral domain, polynomial rings.

References:

Text Books:

1. Linear Algebra by K. Hoffman and R. Kunze.
2. V. Sahai and V. Bist, Algebra, Narosa

Suggested Readings:

3. J.B. Fraleigh, A First Course in Abstract Algebra, Pearson
4. I.N. Herstein, Topics in Algebra, John Wiley & Sons

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UG Semester II

Paper 3: Integral Calculus

Credit: 4 T:04

Course Outcomes:

1. Some of the families and properties of Riemann integrable functions, and the applications of the fundamental theorems of integration.
2. Beta and Gamma functions and their properties.
3. The valid situations for the inter-changeability of differentiability and integrability with infinite sum, and approximation of transcendental functions in terms of power series.
4. Compute area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.

UNIT I

Definite integrals as limit of the sum, Riemann integral, Integrability of continuous and monotonic functions, Fundamental theorem of integral calculus, Mean value theorems of integral calculus, Differentiation under the sign of Integration.

UNIT II

Improper integrals, their classification and convergence, Comparison test, μ-test, Abel's test, Dirichlet's test, quotient test, Beta and Gamma functions.

UNIT III

Rectification, Volumes and Surfaces of Solid of revolution, Pappus theorem, Multiple integrals, change of order of double integration, Dirichlet's theorem, Liouville's theorem for multiple integrals.

UNIT IV

Vector Differentiation, Gradient, Divergence and Curl, Normal on a surface, Directional Derivative, Vector Integration, Theorems of Gauss, Green, Stokes and related problems.

References:

Text Books:

1. T.M. Apostol, Calculus Vol. II, John Wiley Publication.
2. Shanti Narayan, P.K. Mittal, Integral Calculus, S. Chand.

Suggested Readings:

3. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons.

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Paper 4: Geometry

Credit: 4 T: 04

Course Outcomes:

1. To learn and visualize the fundamental ideas of coordinate geometry.
2. To describe some surfaces by using analytical geometry.
3. To gain knowledge about regular geometrical figures and their properties.

Unit I

General equation of second degree, System of conics, Tracing of conics, Confocal conics, Polar equation of conics and its properties.

Unit II

Three-Dimensional Coordinates, Projection and Direction Cosine, Plane (Cartesian and vector form), Straight line in three dimension (Cartesian and vector form).

Unit III

Sphere, Cone and Cylinder.

Unit IV

Central conicoids, Paraboloids, Plane section of conicoids, Generating lines, Confocal conicoids, Reduction of second degree equation.

References:

Text Books:

1. P. R. Vittal, Analytical Geometry
2. S. L. Loney, The Elements of Coordinate Geometry, Macmillan

Suggested Readings:

3. Robert J.T. Bell, Elementary Treatise on Coordinate Geometry of three dimensions, Macmillan India Ltd

Web References:

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UG Semester III

Paper 5: Ordinary Differential Equations

Credit: 4 T:04

Course Outcomes:

1. Formulate Differential Equations for various Mathematical models.
2. Solve first order non-linear differential equation and linear differential equations of higher order using various techniques.
3. Apply these techniques to solve and analyze various mathematical models.

UNIT I

Differential Equations of first order and first degree, variable separable equations and equations reducible to this form, linear equations and Bernoulli equations, Exact differential equations and integrating factors, special integrating factors and transformations. Differential Equations of first order and higher degree, Clairaut equation, singular solutions. Orthogonal trajectories.

UNIT II

Linear Differential Equations with constant coefficients, homogeneous linear equation with constant coefficients, Wronskian, its properties and applications. 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,

UNIT III

Systems of first order equations, linear systems, homogeneous linear systems with constant coefficients, Volterra's prey predator equations,

Existence and uniqueness of solutions, method of successive approximations, Picard's theorem, Application to systems of first order equations.

UNIT IV

Series solutions of differential equations, Power series method. Bessel, Legendre and Hypergeometric functions and their properties, recurrence and generating relations.

References

Text Books:

1. B. Rai, D.P. Choudhary & H.J. Freedman, A Course in Differential Equations.

2. S. L Ross, Differential Equations, 3rd Edition, Wiley

Suggested Readings:

3. G.F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw Hill

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Paper 6: Mechanics

Credit: 4 T:04

Course Outcomes:

1. The significance of mathematics involved in physical quantities and their uses.
2. To understanding the various concepts of basic mechanics like simple harmonic motion, motion under other laws and forces.
3. To study and to learn the cause-effect related to these.
4. The applications in observing and relating real situations/structures.

Unit I

Frame of reference, work energy principle, Forces in three dimensions, Poinsot's central axis, Wrenches, Null lines and planes.

Unit II

Virtual work, Stable and Unstable equilibrium, Catenary, Catenary of uniform strength.

Unit III

Velocities and accelerations along radial and transverse directions, and along tangential and normal directions, Simple Harmonic motion, Motion under other law of forces. Elastic strings, Motion in resisting medium, Constrained motion, Motion on smooth and rough plane curves.

Unit IV

Motion of particles of varying mass, Rocket motion, Central orbit, Kepler's laws of motion, Motion of particle in three dimensions, Rotating frame of

reference, Rotating Earth, Acceleration in terms of different coordinates systems.

References

Text Books:

1. R.C. Hibbeler, Engineering Mechanics-Statistics
2. Nelson, Engineering Mechanics- Dynamics, Tata McGraw Hill

Suggested Readings:

3. J.L. Synge & B.A. Griffith, Principles of Mechanics, Tata McGraw Hill

Web References:

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UG Semester IV

Paper 7: Mathematical Methods

Credit: 4 T:04

Course Outcomes:

1. To develop mathematical skills in calculus and analysis.
2. To get knowledge of Laplace Transforms and Fourier series.
3. To get acquainted with the essentials of calculus of variations.

Unit 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, alternating series, Leibnitz's theorem, absolute and conditional convergence. Sequences and series of functions: point wise and uniform convergence of sequences of functions, consequences of uniform convergence, integration and differentiation of series of functions.

Unit II

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.

Unit III

Fourier series, Fourier expansion of piecewise monotonic functions, Half and full range expansions, Fourier transforms (finite and infinite), Fourier integral.

Unit IV

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, Functionals dependent on more than one independent variable, Variational problems in parametric form.

References:

Text Books:

1. T.M. Apostol. Mathematical Analysis, Pearson
2. RG Bartle, Introduction to Real Analysis, Wiley India

Suggested Readings:

3. G.F. Simmons, Differential Equations with Applications and Historical Notes, Tata- McGraw Hill
4. A.S. Gupta, Calculus of Variations with Applications Prentice Hall India.

Web References:

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Paper 8: Linear & Abstract Algebra

Credit: 4 T:04

Course Outcomes:

1. The fundamental concept of Rings, Fields, subrings, integral domains and the corresponding morphisms.
2. The concept of linear independence of vectors over a field, the idea of basis and the dimension of a vector space.
3. Basic concepts of linear transformations, the Rank-Nullity Theorem, matrix of a linear transformation and the change of basis.
4. Automorphisms for constructing new groups from the given group.
5. Group actions, Sylow theorems and their applications to check nonsimplicity.
6. Compute inner products and determine orthogonality on vector spaces.

Unit I

Automorphism, inner automorphism, automorphism groups and their computations, Conjugacy relations, Normaliser, Counting principle and the class equation of a finite group, Center of group of prime power order, simple groups, Group action, Burnside lemma, Sylow theorems and its applications.

Unit II

Prime and maximal ideals, Euclidean Rings, Principal ideal rings, Polynomial Rings, Polynomial over the Rational Field, The Eisenstein Criterion, Polynomial Rings over Commutative Rings, unique factorization domain.

Unit III

Vector spaces, Subspaces, Linear independence and dependence of vectors, Basis and dimension, Quotient space, Linear transformations, Direct sums, The Algebra of linear transformations, rank nullity theorem, their

representation as matrices, Linear functionals, Dual space, Characteristic values, Cayley Hamilton Theorem.

Unit IV

Inner product spaces, Cauchy-Schwarz inequality, Orthogonal vectors, Orthonormal sets and bases, Bessel's inequality for finite dimensional spaces, Gram-Schmidt orthogonalization process, Bilinear and Quadratic forms.

References:

Text books:

1. Topics in Algebra by I. N. Herstein.
2. Algebra by V. Sahai and V. Bist
3. Linear Algebra by V. Sahai and V. Bist

Suggested Readings:

4. Linear Algebra by K. Hoffman and R. Kunze.

Web References:

Digital platforms web links : NPTEL/SWAYAM/ MOOCS/Openstax.org

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UG Semester V

Paper 9: Numerical Analysis

Credit: 4 T:04

Course Outcomes:

1. Some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
2. Interpolation techniques to compute the values for a tabulated function at points not in the table.
3. Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

Unit 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.

Unit II

Numerical differentiation, Numerical Quadrature: Newton Cotes Formulas, Gaussian Quadrature Formulas, System of Linear equations: Direct method for solving systems oflinear 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.

Unit III

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.

Unit IV

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.

References

Text Books:

1. S. S. Sastry, Introductory Methods of Numerical Analysis, PHI
2. Numerical Methods for Engineering and scientific computation by M. K. Jain, S.R.K. Iyengar & R.K. Jain.

Suggested Readings:

3. Kandasamy P. & et Al., Numerical Methods, S. Chand & Co.

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Paper 10: Analysis

Credit: 4 T:04

Course Outcomes:

1. Understand the basic concepts of metric spaces.
2. Know the concepts such as open balls, closed balls, compactness, connectedness etc.
3. Understand the significance of differentiability of complex valued functions leading to the understanding of Cauchy-Riemann equations.
4. Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.
5. Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues and apply Cauchy Residue theorem to evaluate integrals.

Unit I

Definition and examples of metric spaces, Neighbourhoods, Interior points, Limit Points, Open and closed sets, Convergent and Cauchy sequences, Completeness, Cantor's intersection theorem.

Uniform convergence of sequences and series of functions, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Power series.

Unit II

Stereographic projection, Continuity and Differentiability of complex functions, Analytic functions, Cauchy Riemann equations, Harmonic functions.

Unit III

Complex integration, Cauchy-Goursat theorem, Cauchy's Integral formula, Formulae for first, second and nth derivatives, Cauchy's Inequality, Liouville's Theorem, Elementary functions, Mapping by elementary functions, conformal mapping.

Unit IV

Taylor and Laurent Series, Absolute and uniform convergence of Power series, Residues and Poles, Residue theorem, Zeros and poles of order m, Evaluation of improper real integrals, Definite integrals involving sines and cosines.

References:

Text books:

1. Mathematical Analysis by Shanti Narain.
2. Complex variable and applications by Brown & Churchill.

Suggested Readings:

3. Magnus Robert, Fundamental Mathematical Analysis, Springer Undergraduate Mathematics Series

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Paper 11 A: Integral & Partial Differential Equations

Credit: 4 T:04

Course Outcomes:

1. Describe different types of Linear integral equations and partial differential equations for the impart knowledge of formulation of practical problems of applied mathematics.
2. Understand the theoretical basic behavior of different types of arising problems such as Fredholm, Volterra, Singular, Hilbert and Cauchy integral equations.
3. Explain the foundations of various problems related to Wave, Laplace and Diffusion equations by the method of separation of variables.
4. Deal with problems in applied mathematics, theoretical mechanics and mathematical physics and engineering.

Unit I

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. Cauchy's method of characteristic, Charpit's method of solution, Surfaces orthogonal to the given system of surfaces.

Unit II

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, Solution of second order partial differential equations with variable coefficients, Monge's method of solution, Cauchy's problem for Homogenous wave equation, Properties of Harmonic function, Methods of separation of variable for solving Laplace, wave and diffusion equations.

UNIT III

Linear Integral Equations-Definition and Classification of conditions, Special kinds of Kernels, Eigen values and Eigen functions, Convolution integral, Inner product, Integral equations with separable Kernels. Reduction to a system of algebraic equations.

UNIT IV

Fredholm alternative, Fredholm Theorem, Fredholm alternative theorem, Approximate method, Method of successive approximations, Iterative scheme. Solution of Fredholm and Volterra integral equation, Results about resolvent Kernel.

References:

Text Books:

1. I.N. Sneddon: Elements of Partial Differential Equations, Mc -Graw Hill, 1988.
2. Ram P. Kanwal, Linear Integral Equations (2nd ed.), Birkhäuser, Boston.

Suggested Readings:

3. T. Amarnath: An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, 2005.
4. Tyn Myint U: Partial Differential Equations of Mathematical Physics, Elsevier Publications.

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Paper 11B: Discrete Mathematics

Credit: 4 T: 04

Course Outcomes:

1. Lattices and their types.
2. Boolean algebra, switching circuits and their applications.
3. Graphs, their types and its applications in study of shortest path algorithms.
4. Display familiarity with the mathematical models which are the integral part of the hardware and software of computer science.
5. Elaborate and expand their understanding of the tools helpful in the implementation of circuit design, AI algorithms and compiler construction.

Unit I

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.

Unit II

Boolean Algebra- Basic definitions, Sum of products and products of sums, duality principle, Boolean functions, Logic gates and Karnaugh maps. Lattice, Duality, types of lattices, sublattices, bounded lattices, distributive lattices, complemented lattices, modular lattices, join irreducible elements.

Unit III

Combinatorics- 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.)

Unit IV

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:

Text books:

1. Discrete Mathematics by C. L.Liu.
2. Discrete Mathematics with computer application by Trembley and Manohar.
3. Mendelson, Elliott: Introduction to Mathematical Logic, Chapman & Hall, 1997
4. John E. Hoprcroft, Rajeev Motwani, Jeffrey D. Ullman: Introduction to Automata Theory, Languages and Computation, Pearson Education, 2000

Suggested Readings:

5. Arnold B. H.: Logic and Boolean Algebra, Prentice Hall, 1962
6. K. H. Rosen: Discrete Mathematics and its applications, MGH 1999

Web References:

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Paper 11C: Number Theory

Credit: 4 T:04

Course Outcomes:

1. To have knowledge of primes, congruences, quadratic residues and primitive roots.
2. Solving Diophantine equations.
3. Derive generating functions and recurrence relations.

UNIT I

Divisibility; Euclidean algorithm; primes; congruences; Fermat's theorem, Euler's theorem and Wilson's theorem; Fermat's quotients and their

elementary consequences; solutions of congruences; Chinese remainder theorem; Euler's phi-function. Congruences

UNIT II

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.

UNIT III

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.

UNIT IV

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.

References:

Text Books:

1. Niven, I., Zuckerman, H. S. and Montgomery, H. L. (2003) An Int. to the Theory of Numbers (6th edition) John Wiley and sons, Inc., New York.
2. Burton, D. M. (2002) Elementary Number Theory (4th edition) Universal Book Stall, New Delhi.
3. Balakrishnan, V. K. (1996) Introductory Discrete Mathematics, Dover Publications.

Suggested Readings

4. Balakrishnan, V. K. (1994) Schaum's Outline of Theory and Problems of Combinatorics Including Concepts of Graph Theory, Schaum's Outline.

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Internship / Term Assignment

Credit :04

UG Semester VI

Paper 12: Advanced Algebra

Credit: 4 T:04

Course Outcomes:

1. Give the structure of an abelian group of a given order.
2. Construct the splitting field extension of a given polynomial.
3. Understand the interplay of group theory and field theory.
4. Determine the minimal polynomial of an algebraic element.

Unit I

Series of groups, Schreier theorem, Jordan Holder theorem, solvable groups, Nilpotent groups, Insolvability of Sn for n>5,

Unit II

Finite Abelian groups, primary decomposition theorem, basis theorem, fundamental theorem of finite Abelian group, elementary divisors and invariant factors,

Unit III

Field extensions: finite extension, finitely generated extension, algebraic extension, simple extension, transcendental extension, finite field.

Unit IV

Splitting field, algebraically closed field, normal extension, separable extension, primitive element theorem. Galois theory- Galois group, Galois extension, Fundamental theorem of Galois theory, Artin's theorem, Fundamental theorem of algebra (Algebraic Proof)

References:

Text Books:

1. V. Sahai & V. Bist: Algebra, Fourth Edition, Narosa.
2. J. A. Gallian, Contemporary Abstract Algebra, 4th edition, Narosa
3. DJS Robinson, An Introduction to Abstract Algebra, Hindustan Book Agency.

Suggested Readings:

4. J. B. Fraleigh: A first course in Abstract algebra, Narosa
5. S. Lang: Algebra, Addison Wesley.

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Paper I3: Differential Geometry & Tensor Analysis

Credit: 4 T:04

Course Outcomes:

1. Explain the concept of differentiable geometry.
2. Understand the concepts of tensors in differentiable geometry.
3. Apply various concept of differential calculus in tensors.

Unit I

Local theory of curves-Space curves, Examples, Plane Curves, tangent and normal and binormal, Osculating Plane, normal plane and rectifying plane, 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.

Unit 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, Gauss-Bonnet theorem, Gaussian curvature, normal curvature, Meusneir's theorem, mean curvature, Gaussian curvature, umbilic points, lines of curvature, Rodrigue's formula,Euler's theorem.

Unit III

Tensor algebra: Vector spaces, the dual spaces, tensor product of vector spaces, transformation formulae, contraction, special tensor, inner product, associated tensor.

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, Covariant differentiation.

Unit IV

Gradient of scalars, Divergence of a contra-variant vector, covariant vector and conservative vectors, Laplacian of an invariant, curl of a covariant vector, irrotational vector, Riemannian space, Riemannian curvatures and their properties, Ricci tensor, and scalar curvature, Einstein space and Einstein tensor, Geodesics.

References:

Text books:

1. T.J. Willmore, An introduction to Differential Geometry,Dover Publication 2012.
2. S.Lang., Fundamentals of Differential Geometry; Springer, 1999.
3. B. O'Neil, Elementary Differential Geometry, 2nd Edition, Academic press, 2006.
4. R.S. Mishra, A Course in Tensors with Application to Riemannian Geometry, Pothishala 1988.

Suggested Readings:

5. David C. Kay, Tensor Analysis, Schaum's Outline series McGraw Hill 1988.

Web References:

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Paper 14 A: Advanced Differential Equations

Credit: 4

Course Outcomes: T:04

1. Solve the system of 1st order differential equations, 2nd order differential equations, nth order differential equations, oscillatory equation, stability and unstability of linear and non-linear system of equations.
2. Conceptualize Green's functions and nature of critical points.
3. Prove advanced understanding of topics in applied mathematics, computational physics etc.

Unit I

Linear System- Introduction, properties of linear homogeneous systems, Abel-Liouville formula, Periodic linear System, Floquet's theorem, Solution of nth order linear homogeneous equation with variable coefficients.

Unit II

Inhomogeneous linear system, nth order linear non-homogeneous equation with variable coefficients, Hurwitz's theorem, Non-linear system, Volterra's prey & predator equation, Non linear equations: Autonomous system.

Unit III

The phase plane & its phenomena, types of critical points & Stability, Critical points & stability for linear system, stability by Liapunov's direct method. Green function, Construction of Green functions, Green function of homogeneous and non-homogeneous end conditions, Strum Liouville systems.

Unit IV

Second order differential equation: Introduction, Preliminary results, Boundedness of solutions, Oscillatory equation, number of zeroes, Pruffer's transformation, Strum theorem, Strum's comparison theorem.

References:

Text Books:

1. G. F. Simmons: Differential Equation, Tata McGraw-Hill
2. B. Rai, D. P. Chaudhary, H.I. Freedman: A course in Ordinary Differential Equations, Narosa Publishing House.
3. S. L. Ross: Differential Equations, Wiley Indian, 2004

Suggested Readings:

4. E. A. Coddington: An Introduction to Ordinary Differential Equations

Web References:

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Paper 14 B: Operations Research

Credit: 4 T:04

Course Outcomes:

1. Be able to understand the application of OR and frame a LP Problem with solution
2. Be able to build and solve Transportation and Assignment problems using appropriate method.
3. Be able to design and solve simple models of CPM and queuing to improve decision making and develop critical thinking and objective analysis of decision problems.
4. to take best course of action out of several alternative courses for the purpose of achieving objectives by applying game theory and sequencing models.

Unit I

Linear programming problems, Slack and surplus variables, Statement of general Linear programming Problems, Standard and matrix forms of linear programming problem, Basic feasible solution.

Unit II

Convex sets, Fundamental theorem of linear programming, Simplex method. Artificial variables, Big-M method, Two- phase method, Revised simplex method.

Unit III

Resolution of degeneracy, Duality in linear programming problems, Dual simplex method, Primal-dual relation analysis, integer programming.

UNIT IV

Transportation problems, assignment problems, Queuing Theory, Markov Chains, PERT and CPM, Optimization and constrained Optimization using Langrange's Multiplier.

References:

Text books:

1. Hamdy A. Taha, Operations Research: An Introduction, 10th Edition, Pearson
2. Kanti Swaroop, P. K. Gupta, Manmohan, Operations Research, Sultan Chand

Suggested Readings:

3. G. Hadley, Linear Programming

Web References:

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Minor Project

Credit :04

UG SEMESTER VII

Paper 15: Topology

Credit: 4 T:04

Course Outcomes:

1. Define and illustrate the concept of topological spaces and continuous functions,
2. Illustrate the concept of limit point, dense sets, interior, exterior, boundary points.
3. Identify and understand bases, sub-bases and different type of spaces like Lindelof, Separable, and their properties.

Unit I

Countable and uncountable sets, Schroeder-Bernstein theorem, Cantor's Theorem, Cantor's Sets, Cantor's continuum hypothesis, Zorn Lemma, Well ordering principle.

Topological spaces: Definitions and Examples, open base and open subbase for a topology, Lindelof theorem, limit points, closure, interior; Continuous functions, Homeomorphisms; relative topology, Metric Topology, Product Topology, Weak topology, The function algebras C(X,R) and C(X,C).

Unit II

Compact spaces, Heine Borel theorem, product of spaces, Tychonoff theorem, generalized Heine Borel theorem, locally compact spaces, compactness for metric spaces, Ascoli's theorem.

Unit III

Separation Axioms: T1 and Hausdorff spaces, completely regular and normal spaces, Urysohn's lemma; Tietze extension theorem. Uryohn's imbedding theorem; Stone Cech compactification.

UNIT IV

Connected spaces, the components of a space, totally disconnected space, locally connected space,

References

Text Books:

1. G.F. Simmons: Introduction to Topology and Modern Analysis, Mc-Graw Hill Int. Book Company
2. J. R. Munkres: Topology - A first course, Prentice hall India Pvt. Ltd.

Suggested Readings:

3. J. L. Kelley: General Topology. Van Nostrand. Reinhold Co., New York 1995

Web References:

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Paper 16: Fluid Mechanics

Credit: 4 T:04

Course Outcomes:

1. understand the concept of fluid and their classification, models and approaches to study the fluid flow.
2. formulate mass and momentum conservation principle and obtain solution for non viscous flow.
3. know potential theorems, minimum energy theorem and circulation theorem.
4. understand two dimensional motion, circle theorem and Blasius theorem.

Unit I

Types of fluids, Continuum hypothesis, Lagrangian and Eulerian method of describing fluid motion, Motion of Fluid element: Translation, Rotation and Deformation. Stream lines, Path lines and streak lines. Material derivative. Acceleration of a fluid particle in Cartesian, Cylindrical Polar and Spherical Polar Coordinates. Vorticity Vector, Vortex Lines, Rotational and Irrotational motion of fluid, Rotational velocity, Velocity Potential, Boundary surface, Boundary condition.

Unit II

Reynold transport theorem. Principle of conservation of Mass-Equation of continuity (By Lagrangian and Eulerian method). Equation of Continuity in different coordinate systems. Body force and Surface force. Euler's equation of motion-conservation of momentum, Bernoulli's Equation, Energy Equation, Impulsive effects.

Unit III

Irrotational motion in two dimensions: Stream function, Physical significance of stream function, Sinks, Doublets and their images in two dimension, Complex Velocity Potential. Sources, Milne-Thompson circle theorem, Vortex,

Vortex motion, Image of Vortex, Kelvin Circulation Theorem, Complex potential due to Vortex, Kirchhoff vortex Theorem, Blasius Theorem and Kutta-Joukowski Theorem.

Unit IV

Irrotational motion produced by motion of circular cylinders in an infinite mass of liquid, Liquid Streaming past circular cylinder, Kinetic energy of liquid, Motion of sphere through a liquid at rest at infinity. Liquid streaming past a fixed sphere, Axis-Symmetric flow, Stoke's function.

References:

Text Books:

1. Frank Chorlton: Text Book of Fluid Dynamics, C.B.S. Publishers, Delhi.
2. Z.U.A. Warsi: Fluid Dynamics, Theoretical and Computational Approaches, C.R.C. Press
3. S.W. Yuan: Foundation of Fluid Mechanics, Prentice Hall of India Pvt. Ltd. New Delhi
4. N. Curle and H J Davies: Modern fluid dynamics

Suggested Readings:

5. G. K. Bachelor: An Introduction to Fluid Dynamics. Cambridge University Press. London.
6. R.W. Fox, P.J. Pritchard and A.T. McDonald: Introduction to Fluid Mechanics, Seventh Edition, John Wiley & Sons, 2009.

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Paper 17: Differential Geometry of Manifolds

Credit: 4 T:04

Course Outcomes:

1. Elaborate the concept of differentiable manifolds and their examples.
2. Clarify the concepts of vector fields, tangent vectors & tangent spaces in a manifold.
3. Apply various concepts of differential calculus to the settings of abstract set called manifold.

4. Use Riemannian metric on a given manifold to find the various types of curvatures with emphasis on the surface/ types of manifold.
5. Bring out different connections on Riemannian manifold and its properties.
6. Calculate curvature tensor & tensors of respective connections.

Unit I

Definition and examples of differentiable manifolds, Tangent vectors, Tangent Spaces, Vector fields and their examples, Jacobian map. Immersions and submersions, Diffeomorphism and their examples, Curve in a manifold, Integral curves and their examples, Distributions, Hypersurface of R^n, Sub-manifolds.

Unit II

Standard connection on R^n, Covariant derivative, Sphere map, Weerigarten map, Gauss equation, the Gauss curvature equation and Coddazi-Mainardi equations.

Unit III

Invariant viewpoint, Cartan view point, coordinate view point, Difference Tensor of two connections, Torsion and curvature tensors.

Unit IV

Riemannian Manifolds, Length and distance in Riemannian manifolds, Riemanian connection and curvature, Curves in Riemannian manifolds, Submanifolds of Riemannian manifolds.

References:

Text Books:

1. N.J. Hicks: Notes on Differential Geometry, D. Van Nostrand, 1965.
2. U. C. De., A. A. Shaikh: Differential Geometry of Manifolds, Narosa Publishing House.

Suggested Readings:

3. Y. Matsushima: Differentiable Manifolds, Marcel Dekker, INC. New York, 1972.

Web References:

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Paper 18: Complex Analysis

Credit: 4 T:04

Course Outcomes:

1. Understand the topics of Complex Analysis needed to pursue research in pure mathematics.
2. Understand the properties of maximum modulus of a Complex valued function and the results based on that property.
3. Develop manipulation skills in the use of Rouche's theorem and Argument Principle.
4. Show knowledge of Gamma and Zeta functions with their properties and relationships.
5. Understand the Harmonic functions defined on a disc and concerned results.
6. Make factorization of entire functions having infinite number of zeros.

Unit I

Maximum Modulus Theorem, Schwarz's Lemma, Minimum Modulus Theorem, Hadamard's three circle theorem, automorphism of the unit disk. Convergence of sequences and series of complex numbers, absolute convergence. Uniform convergence of sequence and series of functions, Cauchy's criterion, Weierstrass's M-test, analytic convergence theorem. Absolute and uniform convergence of power series, integration and differentiation of power series, radius of convergence.

Unit II

Zeroes of holomorphic functions, Open Mapping Theorem, Inverse Function Theorem. Index of a closed path, meromorphic functions, argument principle, Rouche's theorem, residueat the point at infinity, indentation around a branch point and the branch cut, summation of series.

Unit III

Function spaces: Hurwitz theorem, Infinite products, Weierstrass factorization theorem, Mittag-Leffler's theorem, Gamma functions and its properties, Riemann's Zeta function.

UNIT IV

Uniqueness of direct analytic continuation, Power series method of analytic continuation, Natural boundary, Schwarz's reflection principle, Harmonic Functions, Mean value property for harmonic functions, Harnack's inequality, Poisson formula, Jensen's formula, Poisson-Jensen's formula, Convex functions, Hadamard's three circle theorem as a convexity theorem, Canonical products, Hadamard's factorization theorem, order of entire functions.

References:

Text Books:

1. J. V. Deshpande: Complex Analysis, Tata McGraw-Hill Publishing Company Limited, New Delhi
2. E. C. Titchmarsh: Theory of functions, Oxford University Press
3. John B. Conway: Functions of one complex variables, Springer International

Suggested Readings:

4. R.V. Churchill, J.W. Brown, Complex Variables and Applications, McGraw Hill.

Web References:

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Paper 19 A: Module Theory

Credit: 4 T:04

Course Outcomes:

1. Identify cyclic modules, simple modules, finitely generated modules etc.
2. Find a basis of a free module.
3. Use the basis to describe module homomorphisms.
4. Describe the structure of a finitely generated module over a PID.

Unit I

Modules-Definition and examples, simple modules, submodules, Module Homomorphisms, Quotient modules, torsion free and torsion modules, direct sum of modules.

Unit II

Exact sequences, Short exact sequence, split exact sequences, Five-lemma, free modules, modules over division rings are free modules, invariant rank property.

Unit III

Free modules over PID's, Invariant factor theorem for submodules, Finitely generated modules over PID, Chain of invariant ideals, Fundamental structure theorem for finitely generated module over a PID,

Unit IV

Projective and injective modules, Divisible group.

References:

Text Books:

1. V.Sahai and V. Bist: Algebra, Fourth Edition, Narosa.
2. I.B.S. Passi and I.S. Luther: Algebra, Volume 3 Modules, Narosa

Suggested Readings:

3. S. Lang: Algebra, Addison Wesley.

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Paper 19 B: Measure Theory & Integration

Credit: 4 T:04

Course Outcomes:

1. Display understanding of the essential foundations of important aspect of mathematical analysis.
2. Explain the measurability of a set of real numbers and measurable functions.
3. Differentiate between the Riemann integral and the Lebesgue integral.
4. Apply the Measure theory and theory of the integral in other branches of pure and applied mathematics.

Unit I

Algebra of sets, countable sets, Cantor set, Borel sets, outer measure of a set and its properties. Measurable sets. Lebesgue measure, a non-measurable set.

Measurable functions and their properties. Concept of almost everywhere. Littlewood's three principles.

Unit II

The Lebesgue integration of bounded function over a set of finite measure, the Lebesgue, Bounded convergence theorem, the integral of a non-negative function, Fatou's Lemma, Monotone convergence theorem, the general Lebesgue integral, Lebesgue convergence theorem.

Unit III

Differentiation of monotone functions, Vitali's Lemma, the four derivatives, the differentiation theorem. Functions of bounded variation, Differentiation of an integral. Absolute continuity.

Unit IV

Inequalities and the Lp Spaces: The Lp Spaces, convex functions, Jensen's inequality, the inequalities of Holder and Minkowski, completeness of Lp(μ). Convergence inmeasure, almost uniform convergence.

References:

Text Books:

1. H.L. Royden: Real Analysis, Pearson Prentice Hall
2. G.de Barra: Measure Theory and Integration, Wiley Eastern Ltd.

Suggested Readings:

3. Taylor, Measure Theory and Integration,American Mathematical Soc., 2006

Web References:

Digital platforms web links: NPTEL/SWAYAM/ MOOCS/Openstax.org

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Research Methodology

Credit: 4 T:04

Course outcomes:

This course is designed to enable students to:

1. Identify and discuss the role and importance of research.
2. Identify and discuss the issues and concepts salient to the research process.
3. Identify and discuss the complex issues inherent in selecting a research problem, selecting an appropriate research design, and implementing a research project.
4. Identify and discuss the concepts and procedures of sampling, data collection, analysis and reporting
5. Read, comprehend and explain research article and writing a research article.

UNIT I

Research Formulation and Design
Motivation and objectives – Research methods vs. Methodology. Steps of research, Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, concept of applied and basic research process, criteria of good research. Defining and formulating the research problem, selecting the problem, necessity of defining the problem, importance of literature review in defining a problem, literature review-primary and secondary sources, reviews, monograph, patents, research databases, web as a source, searching the web.

UNIT II

Data measurement and Data Analysis
Measurement: Concept of measurement, Problems in measurement in research – Validity and Reliability. Levels of measurement – Nominal, Ordinal, Interval, Ratio. Observation and collection of data, methods of data collection, sampling methods, data processing and analysis strategies and tools, data analysis, hypothesis testing.

UNIT III

Soft Computing
Computer and its role in research, some mathematical software like MATLAB, R etc. and their application in research. Software for paper formatting like LaTeX/MS Office.

UNIT IV

Research Ethics and Report Writing

Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Ethical issues related to publishing, Plagiarism, Software for detection of Plagiarism, publishing a research article.

REFERENCES:

1. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International.
2. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers

Suggested Readings:

3. A Manual for Writers of Research Papers, Theses, by Kate L. Turabian, Wayne C Booth, Gregory G. Colomb.

Web references:

https://www.classcentral.com/course/swayam-research-methodology-17760
http://users.cla.umn.edu/~nwaller/math.htm

UG SEMESTER VIII

Major Project

Credit :24