Parvatibai Chowgule College of Arts and Science
(Autonomous)

Accredited by NAAC with Grade 'A+'
Best Affiliated College-Goa University Silver Jubilee Year Award

DEPARTMENT OF MATHEMATICS

SYLLABUS FOR THREE/FOUR YEAR UNDERGRADUATE DEGREE HONOURS PROGRAMME IN MATHEMATICS
(Implemented from the Academic Year 2023-2024 onwards)

COURSE STRUCTURE

SEMESTER	MAJOR CORE	MINOR/ VOCATIONAL	MULTIDISCIPLINARY COURSE (MDC)	VALUE ADDED COURSES (VAC)	ABILITY ENHANCEMENT COURSE (AEC)	SKILL ENHANCEMENT COURSE (SEC)
I	**UG-MAT-101:** Basic Algebra	**UG-MAT-102:** Basic Calculus	**UG-MAT-MDC1:** Statistics I			**UG-MAT-SEC1:** Differential Equations I
II	**UG-MAT-103:** Basic Real Analysis	**UG-MAT-104:** Mathematics for Sciences	**UG-MAT-MDC2:** Mathematics for Competitive Exams			**UG-MAT-SEC2:** Operations Research I
III	**UG-MAT-201:** Mathematical Analysis I	**UG-MAT-203:** Combinatorics	**UG-MAT-MDC3:** Statistics II			**UG-MAT-SEC3:** Numerical Methods
	UG-MAT-					

	202: Algebra I					
IV	**UG-MAT-204:** Mathematical Analysis II	**UG-MAT-VOC1:** Pedagogy of Mathematics				
	UG-MAT-205: Linear Algebra					
	UG-MAT-206: Number Theory I					
	UG-MAT-207: Coordinate Geometry					
V	**UG-MAT-301:** Calculus of Several Variables	**UG-MAT-VOC2:** Probability and Statistics				
	UG-MAT-302: Graph Theory					
	UG-MAT-303: Advanced Analysis					
VI	**UG-MAT-305:** Vector Analysis	**UG-MAT-VOC3:** Operations Research Techniques				
	UG-MAT-306:					

	Complex Analysis					
	UG-MAT-307: Metric Spaces					
	UG-MAT-308: Differential Equations II					
VII	**UG-MAT-401:** Algebra II					
	UG-MAT-402: Advanced Analysis II					
	UG-MAT-403: Topology					
	UG-MAT-404: Functional Analysis					
	UG-MAT-405: Computational Linear Algebra					
VIII	**UG-MAT-406:** Measure Theory					
	UG-MAT-407:					

	Partial Differential Equations					
	UG-MAT-408: Rings and Modules					
	UG-MAT-409: Number Theory II					
	UG-MAT-410: Cryptography					

COURSES IDENTIFIED FOR DOUBLE MAJOR

SEMESTER	DOUBLE MAJOR 1	DOUBLE MAJOR 2
I	**UG-MAT-101:** Basic Algebra	**UG-MAT-101:** Basic Algebra
II	**UG-MAT-103:** Basic Real Analysis	**UG-MAT-103:** Basic Real Analysis
III	**UG-MAT-201:** Mathematical Analysis I	**UG-MAT-201:** Mathematical Analysis I **UG-MAT-202:** Algebra I
IV	**UG-MAT-204:** Mathematical Analysis II **UG-MAT-205:**Linear Algebra **UG-MAT-VOC1:** Pedagogy of Mathematics	**UG-MAT-204:** Mathematical Analysis II **UG-MAT-205:** Linear Algebra
V	**UG-MAT-202:** Algebra I **UG-MAT-301:** Calculus of Several Variables **UG-MAT-VOC2:** Probability and Statistics	**UG-MAT-301:** Calculus of Several Variables
VI	**UG-MAT-304:** Vector Analysis **UG-MAT-305:** Complex Analysis **UG-MAT-307:** Differential Equations II	**UG-MAT-304:** Vector Analysis **UG-MAT-VOC3:** Operations Research Techniques

SEMESTER I

DISCIPLINE-SPECIFIC CORE COURSE

Course Title: BASIC ALGEBRA
Course Code: UG-MAT-101
Marks: 100
Credits: 4
Duration: 60 hours
Course Objectives: To introduce the basic Algebra concepts used in other branches of mathematics.
Course learning outcome: Upon completion of the course the student will be able to:

C01. Apply fundamental concepts of logic like symbolic representation, truth tables, and rules of inference, to construct and evaluate valid arguments and proofs.
C02. Define and interpret the various concepts of sets, and relations.
C03. Apply the concept of Boolean Algebra to the study of logic gates.
C04. Compute and use determinants and matrices
C05. Solve systems of linear equations using Gaussian Elimination

Course Content

Module 1: Logic (15 lectures)

Statements in logic, symbolic representation, connectives, truth-tables. The logic of compound statements: Logical form and logical equivalence, conditional statements, duality law, normal forms, rules of inference, valid and invalid arguments. Quantified statements: Predicates and quantified statements, universal quantifiers, existential quantifiers, and statements with multiple quantifiers. Methods of Proof.

Module 2: Sets and Relations (8 lectures)

The notion of Sets- Subsets - Power sets - Equality of sets - Finite and Infinite sets - Set operations - De-Morgan's laws – The cartesian product of sets, Relations - Types of relations - Binary relation - Equivalence relations, Partial Orderings, Equivalence classes, and partitions.

Module 3: Boolean Algebra (12 lectures)

Boolean Functions, Study of logic gates: AND, OR, NOT, XOR, XNOR, NAND, and NOR gates, Minimization of Circuits.

Module 4: Matrices and determinants (25 lectures)

Matrices, Algebra of Matrices, Determinants of a square matrix, Inverse of a square matrix- Elementary Row, Column operations- Elementary matrices- the inverse of a matrix using elementary operations- Rank of a Matrix- Normal Form- Row-Echelon form of a matrix, Row rank and column rank of a matrix, Concept of Linear Independence, Linear Equations: the system of homogeneous equations, Consistency and solution of a system of linear equations using Gaussian Elimination.

List of books recommended for reference

1. Rosen, K.H. (2012), *Discrete Mathematics and its Applications* (7th Ed.), Mc Graw Hill
2. R.D. Bhatt, *Algebraic Structures*, Vipul Prakashan
3. C.L.Liu, *Discrete Mathematical Structures*,

4. Shanti Narayan and P.K.Mittal, *A textbook of Matrices*, S. Chand and Company
5. K.B.Datta*, Matrix and Linear Algebra*, PHI
6. S. Lang, *Introduction to Linear Algebra*, Second Ed., Springer-Verlag

Course Title: BASIC CALCULUS
Course Code: UG-MAT-102
Marks: 100
Credits: 4
Duration: 60 hours
Course Objectives: To introduce the number system with its geometrical properties and axioms of real numbers
Course learning outcome: Upon completion of the course, the student will be able to
C01. Construct real numbers
C02. Use properties of real numbers in the analysis
C03. Draw and recognize graphs of some important functions
C04. Understand the concepts of limit and continuity
C05. Analyse if the functions are differentiable

Course Content
Module 1: Number System:-. (20 lectures)

Simple Algebraic development from Natural numbers to Real numbers. The geometry of Real numbers:- Representation of real numbers on a line, Trichotomy Law, Order on R, Archimedes property, Hausdorff property, distance concept: absolute value (all inequalities ex. Triangle inequality). Subsets of R: bounded-unbounded sets, bounded sets, lub. glb. Completeness axiom, intervals, open-closed intervals, open/closed nbd. of a point, limit points, dense set (Q and Q' only), the concept of infinity

Module 2: Functions:- (10 lectures)

Examples of functions with graphs ($log\ x, a^x, x^n,$ trigonometric functions, step function, absolute value function, polynomial/rational functions, signum function.) Inverse function:- How /why to restrict domain/ co-domain (range), graphs of inverses of above functions, Compositions, addition, the product of functions.

Module 3:Limits and Continuity:- (15 lectures)

Limit of a function (Limit at ∞ and lim ---› ∞) , Algebra of limits, continuous functions(ε−δ definition), types of discontinuity,

Module 4: Differentiable functions :- (15 lectures)

Definition, properties, theorems, increasing/decreasing functions, Taylor's theorem, Newton's Method, L'Hospital's rules, maxima-minima, MVTs. Applications of differentiable functions

List of books recommended for reference

1) Apostol Tom, *Calculus Vol. I*. Second Edition. Wiley Students Edition, India, 2012.
2) G.B Thomas, *Thomas' Calculus*, Pearson Publication.
3) Malik S.C. and Arora Sarita. *Mathematical Analysi*s, Second edition. Wiley Eastern Ltd, 1994.
4) Narayan Shanti. *Differential Calculus*. S. Chand and Company Pvt. Ltd. 1988.

5) Goldberg Richard R., *Methods of Real Analysis*. Oxford and IBH Publishing Co. Pvt. Ltd. Indian Edition, 1970.
6) Bhat R.D. *A Textbook of Mathematical Analysis II*. Vipul Prakashan, First Edition.

MULTDISCIPLINARY COURSES (MDC)

Course Title: Statistics I
Course Code: UG-MAT-MDC1
Marks: 75
Credits: 3
Duration: 45 hours
Course Objectives: To develop the student's ability to use and interpret properly some of the basic statistical concepts.
Course learning outcome: Upon completion of the course, the student will be able to

CO1 Understand the relevance of statistics
CO2 Calculate and interpret the measures of central tendency and dispersion.
CO3 Solve and Interpret correlation and regression problems
CO4 Use Excel to find measures of central tendency and dispersion and coefficient of correlation

Course Content

Module 1: Introduction to Statistics (12 lectures)
Definition, importance, and scope of statistics, limitations of statistics. Data collection, primary and secondary data, data collection methods, classification and tabulation of data, construction of frequency distribution tables, cumulative frequency distribution table. Graphical representation of data: Histogram, frequency polygon, ogives. Diagrammatic representation of data: bar diagrams, pie diagrams.
Module 2: Univariate Statistics (18 lectures)
Measures of central tendency: Arithmetic mean, median, mode. Quartiles, deciles, percentiles. Locating mode, median, quartiles, deciles, and percentiles using graphs. Measures of dispersion: Range, Mean deviation, Standard Deviation, Coefficient of Variation. Skewness and Kurtosis.
Module 3: Correlation and Regression (10 lectures)
Introduction to correlation, types of correlation, scatter diagram, Karl Pearson's correlation coefficient, Spearman's Rank correlation coefficient. Linear and non-linear regression, Lines of regression, coefficients of regression.
Module 4: Excel (5 lectures)
Introduction to Excel, Simple arithmetic and statistical calculations, plotting graphs and diagrams.

List of books recommended for reference

1. S.C. Gupta, *Fundamentals of Statistics,* Himalayan Publishing House
2. B.L. Agarwal, *Basic Statistics,* New Age International

SKILL ENHANCEMENT COURSE (SEC)

Course Title: Differential Equations I
Course Code: UG-MAT-SEC1
Marks: 75
Credits: 3
Duration: 45 hours
Course Objectives: To introduce some methods of solving ODE of first and higher order, applications of the same in different fields.
Course learning Outcomes: Upon completion of the course, the student will be able to
C01. Understand the fundamental concepts of ordinary differential equations, their origin, and geometrical interpretation
C02. Learn various techniques for getting exact solutions of solvable first order differential equations and linear differential equations of higher order.
C03. Grasp the concept of a general solution of a linear differential equation of an arbitrary order and also learn a few methods to obtain the general solution of such equations.
C04. Formulate mathematical models in the form of ordinary differential equations to obtain possible solutions to the day-to-day problems arising in different disciplines.

Course Content

Module 1: **(15 lectures)**

Introduction. Some simple situations where we come across ODE, the Geometrical Meaning of ODE, and Solutions of an ODE. Picard's Existence and Uniqueness theorem. First order ODE. Variable separable, Homogeneous, Non- Homogeneous, Exact differential equations, integrating factor, linear differential equations, Bernoulli equations.

Module 2: **(15 lectures)**

Second-order differential equations, Homogeneous and non-homogeneous differential equations, complementary function, particular integral, Wronskian, Solution space, General solution, complex solutions. Some methods of solving second-order differential equations (undetermined coefficients, variation of parameters, using one solution to find another). Finding particular integral by operator method.

Module 3: **(15 lectures)**

Linear differential equations of higher order, simple examples of non-homogenous differential equations. Some application of differential equations, LR / LCR circuits, SHM (simple-damped-forced), Equation of Catenaries, Planetary Motions – Kepler's Laws.

List of books recommended for reference

1. Simmons G.F., *Differential Equations with Historical Notes*, Tata McGraw Hill

2. Boyce W.E. & DiPrima R.C., *Elementary Differential Equations and Boundary Valued Problems*, John Wiley Pvt Ltd.
3. Braun C, *Differential Equations and Their Applications: An Introduction to Applied Mathematics* (Texts in Applied Mathematics), springer.
4. Coddington E., *Theory of Ordinary Differential Equations*, Tata McGraw Hill
5. Rainville E.D., *Elementary Differential Equations*, Pearson

SEMESTER II

Course Title: BASIC REAL ANALYSIS
Course Code: UG-MAT-103
Marks: 100
Credits: 4
Duration: 60 hours
Course Objectives: To introduce the number system with its geometrical properties and axioms of real numbers
Course learning outcome: Upon completion of the course, the student will be able to
C01. Construct real numbers
C02. Use properties of real numbers in analysis
C03. Draw and recognize graphs of some important functions
C04. Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and calculate the limit superior, limit inferior, and the limit of a bounded sequence.
C05. Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

Course Content

Module 1: Number System **(20 lectures)**

Simple Algebraic development from Natural numbers to Real numbers. Representation of real numbers on a line, Tricotomy Law, Order on R, Archimedes property, Hausdorff property, distance concept: absolute value (all inequalities ex. Triangle inequality).$\mathbb{R}\mathbb{R}$: bounded-unbounded sets, bounded sets, lub. glb. Completeness axiom, intervals, open-closed intervals, open/closed nbd. of a point, limit points, dense set (Q and Q' only), concept of infinity

Module 2: Functions **(7 lectures)**

Examples with graphs ($\log x$, a^x, x^n, trigonometric functions, step function, absolute value function, polynomial / rational functions, signum function.) Inverse function:- How /why to restrict domain/ co-domain (range), graphs of inverses of above functions, Compositions, addition, product of functions.

Module 3: Sequences **(17 lectures)**

Definition, examples, convergence/ divergence of sequence, types of sequences, Cauchy sequences, Sub sequences, absolute convergence, all theorems, Bolzano Weierstrass theorem.

Module 4: Series **(17 lectures)**

Definition, Examples, alternate series, Convergence, Cauchy criteria, absolute convergence, rearrangement of series, All theorems for testing the convergence (absolute and non-absolute),

List of books recommended for reference

1),R.G.Bartle and D. Sherbert, *Introduction to Real Analysis*, Wiley
2)Robert Sticartz, *The Way of Analysis*, Jones and Bartlett Publishers
3)T. Apostol, *Calculus (volume I)*, Wiley Eastern Ltd.
4)S.C. Malik, Savita Arora, *Mathematical Analysis,* New Age International Publishers

Course Title: MATHEMATICS FOR SCIENCES
Course Code: UG-MAT-104
Marks: 100
Credits: 4
Duration: 60 hours
Course Objectives: To build the foundation in Numerical Methods and Linear algebra
Course learning Outcomes: Upon completion of the course, the student will be able to
CO1: Apply interpolation methods to solve problems numerically
CO2: Numerically determine the roots of equations
CO3: Understand the properties of vector spaces
CO4: Relate matrices and linear transformations
CO5: Compute eigen values and eigen vectors

Course Content

Module 1: Interpolation and Extrapolation (15 lectures)
Operators- Δ, and E (Definitions and some relations among them), finite difference tables. Newton Gregory Forward and backward interpolation formulae for equal intervals. For unequal intervals- Lagrange's Formula and Newton's divided difference formula (No proof) and examples

Module 2: Numerical Integration and Differentiation (10 lectures)
Trapezoidal rule, Simpson's $1/3^{rd}$ and $3/8^{th}$ rules (with proof), and problems. Weddle's rule (no proof, only problems), Numerical differentiation, and examples

Module 3: Numerical Solutions of Equations (10 Lectures)
To find a real root of an algebraic or transcendental equation using the Bisection method, regular falsi method, Newton Raphson method with geometrical significance and problems and method of iteration. Gauss-Seidel method to solve simultaneous equations.

Module 4: Linear Algebra (25 lectures)
Vector space [Definition and examples], subspaces, Linear span, linear dependence, independence, and their properties. Basis, dimension of a vector space. Linear transformation, Kernel, and Range of a Linear Transformation. Matrix representation of linear transformation, Rank Nullity theorem. Eigen values and Eigen vectors of a linear transformation and matrices. Diagonalization

List of books recommended for reference

1. Chatterji P.N, *Numerical Analysis,* Rajhans Prakashan Mandir
2. Sastry S.S, *Introductory Methods of Numerical Analysis*, Prentice Hall India
3. Krishnamurty, *An Introduction to Linear Algebra* , Affiliated East-West Press

MULTDISCIPLINARY COURSES (MDC)

Course Title: Mathematics for competitive examination
Course Code: UG-MAT-MDC2
Marks: 75
Credits: 3
Duration: 45 hours
Course Objectives: To make students aware of different types of questions asked in such examinations, logical thinking, and data interpretation.
Course learning outcome: Upon completion of the course, the student will be able to

CO1	Solve with speed and accuracy the MCQ-type questions asked at various examinations
CO2	Think logically to solve problems.
CO3	Improve their thinking ability.

Course Content

1. Numerals (integers, rationales, real numbers) Place values, face values, Prime numbers, Composite numbers, co-prime numbers, and Binary Numbers.
2. Divisibility test for 2,3,4, 5, 6, 8, 9, etc. Division algorithm, Progressions, ratio, proportions (direct, indirect), Percentages, LCM, HCF.
3. Averages, Square root, cube root, square, cube, surds and indices, logarithms. Linear – Quadratic equations, Simultaneous Equations, and Some special cases of higher degree polynomial equations.
4. Time and work, Time and distance, speed and velocity, Trains and boats, stream problems, pipes & containers.
5. Problems on Age, Averages, simple & compound interest, profit &loss, Partnership, stock & shares, True discount, and Banker's discount.
6. Calendar, clock, race, games, logical problems, Logical gates.
7. Area, volumes, surface area, three-dimensional perspectives, Height & distance.
8. Permutation & combinations, Probability, the odd man out, series.
9. Data interpretation, Tables, bar graphs, pie charts, line graphs, curves.

Note: Most classes will be allotted to solving problems

List of books recommended for reference

1) R.S.Agarwal, *Quantitative Aptitude for Competitive Exams*, S.Chand
2) Arun Sharma, *Quantitative Aptitude for CAT,* McGraw Hill

SKILL ENHANCEMENT COURSE (SEC)

Course Title: Operations Research I
Course Code: UG-MAT-SEC2
Marks: 75
Credits: 3
Duration: 45 hours
Course Objectives: This course aims to teach linear programming
Course learning Outcomes: Upon completion of the course, the students will be able to

C01. Analyse and solve linear programming models of real-life situations.
C02. Provide graphical solutions of linear programming problems with two variables, and illustrate the concept of convex set and extreme points.
C03. Know about the relationships between the primal and dual problems
C04. Analyse the optimal solution for various parametric and structural changes
C05. Solve the transportation, assignment problems.

Course Content

Module 1. Linear Programming Problem and Simplex Method (18 Hours)

Definition of standard form, formulation of LPP, convex set and their properties, extreme points. Graphical solution of LPP (Only two variables).Simplex method, Cases pertaining to the existence of multiple solutions, unbounded and no feasible solution. Big M method and two-phase Simplex method.

Module 2. Duality and post optimal analysis: (17 Hours)

General Primal-Dual Pair, Formulating Dual problem, Primal-duel pair in matrix Form, Duality theorems, Duality and simplex Method. Change in Objective function/ constraint/activity coefficients, Structural changes.

Module 3. Transportation and Assignment Problems: (10 Hours)

Mathematical formulation of Transportation Problem, condition for the existence of feasible solution, Initial basic feasible solution by (i) NWC method (ii) Matrix-minima and (iii) VAM, Modi's method to find an optimal solution, balanced and unbalanced transportation problems.

Mathematical formulation of Assignment problem, Hungarian methods to solve assignment problems, balanced & unbalanced assignments problems

List of books recommended for reference

1. Kanti Swarup, Gupta P.K, Man Mohan, *Operations research*, S Chand
2. N.Paul Loomba, *Linear Programming: An Introductory Analysis,* McGraw Hill
3. Taha H, *Operation Research*, Pearson

Semester III
DISCIPLINE-SPECIFIC CORE COURSE

Course Title: MATHEMATICAL ANALYSIS I

Course Code: UG-MAT-201

Marks: 100

Credits: 4

Duration : 60 hours

Prerequisites: Basic Real Analysis

Course Objective: To gain a solid understanding of calculus concepts, limits, continuity, differentiation, and their applications in various domains.

Course learning Outcomes: After completion of this course students will be able to

CLO1 Develop an understanding of limits, including limits at infinity, and calculate limits algebraically and graphically.
CLO2 Understand the epsilon-delta definition of continuity, pointwise and uniform.
CLO3 Analyze continuous functions on closed and bounded intervals.
CLO4 Prove and explain the various results of differentiation.
CLO5 Find the roots of continuous functions using various methods.
CLO6 Apply differentiation techniques to analyze real-world scenarios in physics, economics, and other fields.

Course Content:

Module 1: Continuous Functions (25 lectures)
Limit of a function (Limit at ∞ and lim ---› ∞) , Algebra of limits, continuous functions(ε−δ definition), types of discontinuity, sequential continuity, continuous functions on closed and bounded intervals , their properties, All results of continuous function, IVT , uniform continuity,

Module 2: Differentiable functions (25 lectures)
Definition, properties, theorems, increasing/decreasing functions, Taylor's theorem, L'Hospital's rules, maxima-minima, MVTs. , convex / concave functions, singular points.

Module 3: Applications (10 lectures)
Bisection method and Newton's method to find root of a continuous functions
Application of limits, continuity and differentiation in Physics, Economics and other subjects.

List of Books recommended for reference:

1. Bartle Robert G. and Sherbert Donald R. *Introduction to Real Analysis*, Third Edition. Wiley Student edition.
2. Malik S.C. and Arora Sarita. *Mathematical Analysis*, Second edition. Wiley Eastern Ltd, 1994.

3. Apostol Tom, *Calculus Vol. I*. Second Edition. Wiley Students Edition, India, 2012.
4. Narayan Shanti. *Differential Calculus*. S. Chand and Company Pvt. Ltd. 1988.
5. Goldberg Richard R., *Methods of Real Analysis*. Oxford and IBH Publishing Co. Pvt. Ltd. Indian Edition, 1970.
6. Bhat R.D. *A Textbook of Mathematical Analysis II*. Vipul Prakashan, First Edition.

Course Title: ALGEBRA I

Course Code: UG-MAT-202

Marks: 100

Credits: 4

Prerequisites: Basic Algebra

Course Objectives: To provide a comprehensive introduction to abstract algebra, equipping students with a strong foundation in algebraic structures and their properties.

Course Learning Outcome: Upon completion of the course, the student will be able to

CLO1 understand the fundamental algebraic structures, including groups and rings

CLO2 investigate the properties of algebraic structures with the help of examples.

CLO3 apply theorems and techniques from group theory and ring theory to solve a variety of mathematical problems

CLO4 prove and explain key theorems and concepts related to groups, rings, substructures, and homomorphisms

Course Content

Module 1: (10 Hours)

Definition and Examples of Groups, Elementary Properties of Groups, finite and infinite groups, Subgroups-definition and examples, Subgroup Tests

Module 2: (15 hours)

Cyclic Groups, Cosets, Properties of Cosets, Lagrange's Theorem and consequences. Permutation Groups, Normal Subgroups, Factor Groups,

Module 3: (15 Hours)

Isomorphisms definition and examples, Properties of Isomorphism., Cayley's Theorem, Automorphisms, Homomorphisms, Properties of Homomorphisms, The Isomorphism theorems.

Module 4: (20 Hours)

Rings-definition and examples, Properties of Rings, Subrings, Integral Domains, Fields, Characteristic of a Ring, Ideals and Factor Rings, Prime Ideals and Maximal Ideals, Ring Homomorphisms, properties and examples, The Field of quotients.

List of books recommended for reference:

1) Gallian J, *Contemporary Abstract Algebra*, Cengage Learning
2) Fraleigh J.B., *A First Course in Abstract Algebra*, Pearson
3) Herstein I.N., *Topics In Algebra*, Wiley

4) A.R.Vaisishtha, *Modern Algebra,* Krishna Publications

Course Title: COMBINATORICS

Course Code: UG-MAT-203

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To develop a strong understanding of combinatorial principles, generating functions, recurrence relations, and the principle of inclusion and exclusion, enabling students to apply these concepts to solve a wide range of counting and combinatorial problems

Course Learning Outcome: - Upon completion of the course, the students will be able to

CLO1: Apply fundamental counting principles to solve combinatorial problems.

CLO2: Utilize generating functions to model and solve problems

CLO3: Solve linear recurrence relations with constant coefficients using the characteristic equation method and generating function techniques.

CLO4: Analyze and generate permutations and combinations with constraints

Module I: - Counting principles **(15 Hours)**

Basic Counting Principles, the principle of inclusion and exclusion, Pigeonhole Principle, Permutation and Combination, Binomial theorem, Multinomial theorem,

Module II: - Generating Functions **(15 Hours)**

Generating functions for combinations, Enumerators for permutations, distribution of distinct objects into identical cells. Exponential generating function

Module III: - Recurrence Relations **(15 Hours)**

Linear recurrence relations with constant coefficients, Characteristic equation method, Solutions by generating function technique

Module IV: - Generating Permutations and Combinations (15 Hours)

Combinations with Repetition, Derangements,. Permutations with Forbidden Positions, Consecutive and non-consecutive permutations

REFERENCES:

Mandatory References:

1. Brualdi, R. A. (2004). *Introductory Combinatorics*. Pearson Education India.

Supplementary References:

1. Tucker, A. (2012). *Applied combinatorics*. J. Wiley & Sons, Cop.
2. Graham, R. L., Knuth, D. E., & Patashnik, O. (1994). *Concrete Mathematics*. Addison-Wesley Professional.
3. Door Chuan-Chong Chen, & Koh, K. M. (2012). *Principles and techniques in combinatorics*. World Scientific.
4. Berge. (1971). *Principles of Combinatorics*. Academic Press.
5. Stanley, R. P. (1997). *Enumerative combinatorics*. Cambridge University Press.

SKILL ENHANCEMENT COURSE

Course Title: Numerical Methods

Course Code: UG-MAT-SEC 3

Marks: 75

Credits: 3

Duration: 45 hours

Course Objectives: To equip students with a strong foundation in numerical methods and mathematical techniques, enabling them to solve complex mathematical problems and apply their knowledge in various domains.

Course learning outcome: Upon completion of the course the student will be able to:

CLO1 round off numbers, compute errors, and deal with significant figures in numerical calculations.

CLO2 create and use finite difference tables for purposes such as estimating derivatives and interpolating data.

CLO3 apply numerical integration methods to approximate definite integrals of functions

CLO4 apply root-finding techniques to find real roots of algebraic or transcendental equations, with a clear understanding of the geometric significance of these methods.

CLO5 use the method of least squares for fitting linear, polynomial, and exponential curves to data points and understand the practical applications of curve fitting in various fields.

Course Content:

Module 1: Finite differences and interpolation (15 lectures)

Approximate numbers, significant figures, rounding off numbers, Error- Absolute, relative and percentage

Operators- Δ, ∇ and E (definitions and some relations among them), finite difference tables, fundamental theorem on differences of a polynomial, and examples.

Newton Gregory Forward and backward interpolation formulae (with deduction of formulae) and examples (for equal intervals)

For unequal intervals- Lagrange's Formula and Newton's divided difference formula and examples

Module 2: Numerical Integration and Differentiation (15 lectures)

Trapezoidal rule, Simpson's $1/3^{rd}$ and $3/8^{th}$ rules (with proof) and problems. Weddle's rule (no proof, only problems)

Numerical differentiation and examples.

Module 3: Numerical Solutions of Equations (15 Lectures)

To find a real root of an algebraic or transcendental equation using the Bisection method, regular falsi method, Newton Raphson method with geometrical significance and problems and method of iteration.

Curve fitting: Method of least squares- fitting a line, second-degree polynomial, exponential curve and examples

List of books recommended for reference:

1. Atkinson K., *An Introduction to Numerical Analysis*, John Wiley & Sons
2. Chatterji P.N, *Numerical Analysis*
3. Comte S.D and Carl de Boor, *Elementary Numerical analysis - An Algorithmic approach*, McGraw Hill
4. Hildebrand F.B, *Introduction to Numerical Analysis*, McGraw Hill
5. Sastry S.S, *Introductory Methods of Numerical Analysis*, Prentice Hall India
6. Scarborough J.B, *Numerical Mathematical Analysis*, Oxford and IBH Publishing Company, New Delhi.

MULTIDISCIPLINARY COURSE

Course Title: STATISTICS II

Course Code: UG-MAT-MDC3

Marks: 75

Credits: 3

Prerequisites: Statistics I

Course Objectives: To build a strong foundation in probability and statistics, enabling students to analyze data, make informed decisions, and apply statistical concepts in their field of study.

Course Learning Outcome: Upon completion of the course, the student will be able to

CLO1 understand basic probability concepts, including sample spaces, events, and probability axioms.

CLO2 use different probability distributions, including binomial, Poisson, and normal distributions, and understand how to work with random variables.

CLO3 explore various sampling techniques

CLO4 perform various methods for hypothesis testing and interpret the results in different scenarios

Course Content:

Module 1: Probability **(10 lectures)**

Random Experiment and Sample space, Events, Independent and Mutually Exclusive Events, Conditional Probability, Addition and Multiplication Rule, Baye's Theorem.

Module 2: Probability Distributions **(15 lectures)**

Binomial Distribution, Poisson Distribution, Normal Distribution

Module 3: Sampling **(5 lectures)**

Definition of Sampling, Population, and Sample, Sample survey vs Census, Types of Sampling: Simple random sampling, Stratified sampling, systematic sampling, cluster sampling, multistage sampling, Quota Sampling,

Module 4: Significance tests **(15 lectures)**

Testing of hypothesis, tests of significance, Null and Alternative hypothesis, Chi-square distribution, chi-square test of goodness of fit, chi-square test for independence of attributes, t-distribution, t-test for means, ANNOVA test.

List of books recommended for reference

1. S.C. Gupta, *Fundamentals of Statistics,* Himalayan Publishing House
2. B.L. Agarwal, *Basic Statistics,* New Age International

Semester IV

DISCIPLINE-SPECIFIC CORE COURSE

Course Title: Mathematical Analysis II

Course Code: UG-MAT-204

Marks: 100

Credits: 4

Duration: 60 hours

Prerequisites: Mathematical Analysis I

Course objective:- To acquire a comprehensive understanding of Riemann and Darboux integrals and their practical applications in mathematics.

Course learning outcome:- After completion of this course students will be able to

CLO1 understand Riemann sums and analyze their role in approximating definite integrals.

CLO2 Identify Darboux integrable functions using upper and lower sums and prove related theorems.

CLO3 Apply the fundamental theorems of integration and associated results to solve complex integration problems.

CLO4 Define and identify cases of improper integration, and calculate β and γ functions for specific functions.

CLO5 compare the relations between the different types of integrals.

Course Content:

Module 1: Riemann integrals:- **(15 lectures)**

Tagged partition, Riemann sum, Riemann integrable functions, some simple results on integrable functions using Riemann sum.

Module 2: Darboux integrals **(15 lectures)**

Upper/lower sum, integrable function, Riemann criteria of integrable function, classes of integrable function

Module 3: Fundamental Theorems **(15 lectures)**

Fundamental theorems of integration and their applications (chain rule, substitution and product rule theorems)

Module 4: Improper Integration **(15 lectures)**

Improper integration(Type I and II) , β and γ functions.

References:

1. Bartle Robert G. and Sherbert Donald R. *Introduction to Real Analysis*, Third Edition. Wiley Student edition.

2. Malik S.C. and Arora Sarita. *Mathematical Analysi*s, Second edition. Wiley Eastern Ltd, 1994.
3. Apostol Tom, *Calculus Vol. I*. Second Edition. Wiley Students Edition, India, 2012.
4. Narayan Shanti. *Differential Calculus*. S. Chand and Company Pvt. Ltd. 1988.
5. Goldberg Richard R., *Methods of Real Analysis*. Oxford and IBH Publishing Co. Pvt. Ltd. Indian Edition, 1970.
6. Bhat R.D. *A Textbook of Mathematical Analysis II*. Vipul Prakashan, First Edition.

Course Title: LINEAR ALGEBRA

Course Code: UG-MAT-205

Marks: 100

Credits: 4

Duration: 60 hours

Prerequisites: Basic Algebra

Course Objectives: To provide students with a solid theoretical understanding of vector spaces, subspaces, and the fundamental concepts of linear algebra.

Course Learning Outcome:

CLO1 understand vector spaces, including their properties, definitions, and examples
CLO2 identify subspaces, determine linear independence, and establish relationships between subspaces within a vector space.
CLO3 represent linear transformations using matrices and understand the connection between linear transformations and matrix operations.
CLO4 Compute and analyse eigenvalues and eigenvectors
CLO5 explore inner product spaces, and orthogonality, and apply the Gram-Schmidt process to find orthogonal bases.

Course Content

Module 1: Vector Spaces **(15 lectures)**

Vector space -definition and examples, subspaces, sum and direct sum of subspaces. Linear span, linear dependence, independence and their properties. Finite dimensional vector space, Basis, dimension of a vector space. Dimension of sum of subspaces. Existence of complementary subspace of a finite-dimensional vector space. Quotient space and its dimension.

Module 2: Linear Transformations **(15 lectures)**

Linear transformation, Kernel and Range of a Linear Transformation. Matrix representation of linear transformation, composition of linear maps, change of basis, similar matrices, Rank Nullity theorem.

Module 3: Eigen values and Eigen Vectors **(15 lectures)**

Eigen values and Eigen vectors of a linear transformation and matrices. Eigen space, Algebraic and Geometric Multiplicity of an eigenvalue. Diagonalisability of an n x n matrix over IR

Module 4: Inner Product Spaces **(15 lectures)**

Inner products spaces. Cauchy- Schwarz inequality, Triangle inequality, orthogonal vectors, orthogonal complement, orthogonal sets and bases, Gram-Schmidt Process

List of books recommended for reference

1. Hoffman K. & Kunze R., *Linear Algebra* , PHI
2. Vasishtha A.R., *Linear Algebra,* Krishna Prakashan
3. Kumaresan S., Linear Algebra: A Geometric Approach, PHI
4. Anton H, Elementary Linear Algebra, Wiley Pvt. Ltd.
5. Strang G., Linear Algebra and its Applications, Cengage Learning

Course Title: NUMBER THEORY I

Course Code: UG-MAT-206

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To provide students with an understanding of key concepts in number theory and equip them with the skills needed to solve various types of number theory problems.

Course Learning Outcome: After completion of the course, the student will be able to

CLO1 apply fundamental number theory concepts to solve a variety of integer-related problems.

CLO2 solve congruence and Diophantine equations and apply the techniques to real world problems.

CLO3 determine the prime factorization of integers and apply this knowledge in various contexts.

CLO4 understand the mathematical implications of Fermat's and Wilson theorems.

CLO5 explore number theoretic functions and use these functions to solve problems

Course Content:

Module 1: Divisibility: **(15 lectures)**

Division Algorithm, Greatest Common divisor, Euclidian Algorithm, Fundamental Theorem of Arithmetic, Linear Diophantine equations $ax+by=c$

Module 2: Congruence: **(15 lectures)**

Basic properties, Linear Congruence, Chinese Remainder Theorem, Quadratic Congruence.

Module 3: Fermat's Theorem: **(15 lectures)**

Fermat's and Wilson's Theorem, the equation $x^2+y^2=z^2$, Fermat's Last Theorem.

Module 4: Number Theoretic Functions: **(15 lectures)**

Sum and number of divisors, Mobius function, Mobius Inversion, greatest integer function, Euler's phi function

List of books recommended for reference

1. Burton David, *Elementary Number Theory*, 2012, Mc Graw Hill, 7th Edition.
2. Niven & Zuckerman, *An Introduction to the Theory of Numbers*, Wiley Publications
3. Adams & Goldstein, *Introduction to Number Theory*, Prentice Hall
4. Baker Alan, *A concise introduction to the Theory of Numbers*, Cambridge University Press
5. Telang S.G. & Nadkarni M.D, *Number Theory*

Course Title: Coordinate Geometry

Course Code: UG-MAT-207

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To build a strong foundation in coordinate systems, conic sections, three-dimensional geometry, and curve tracing, solve a wide range of mathematical problems, and apply these concepts in various fields of science and engineering.

Course learning outcome: Upon completion of the course the student will be able to:

CLO1 differentiate between Cartesian, Polar, Cylindrical, and Spherical coordinate systems and apply the appropriate system to represent points and solve geometric problems.
CLO2 derive equations for various geometrical objects, and understand their significance in geometric applications.
CLO3 analyze how translation and rotations of axes affect the equations and properties of geometric objects.
CLO4 classify quadratic equations based on their standard forms and sketch their diagrams.
CLO5 apply calculus concepts to analyze and sketch curves in rectangular and polar coordinates.

Course Content:

Module 1: Coordinate systems (15 lectures)

Coordinate systems: Cartesian, Polar, Cylindrical, and Spherical coordinate systems and relations between them.
Equations of a straight line, plane, and circle in two dimensions.
Transformation of Coordinates: translation and rotation and its effect on the equation of geometrical object.

Module 2: Conic Sections (15 lectures)

Conic Sections: ellipse, parabola, and hyperbola. Their equations, properties, and their graphs.
General equation of second degree in two variables. Reduction to standard form. Techniques for sketching parabola, ellipse, and hyperbola.

Classification of quadratic equations representing lines, parabolas, ellipses, and hyperbolas.

Module 3: Geometry of three dimensions: (15 lectures)

Concepts of the plane, straight line, sphere, cone, cylinder, their equations, and properties

Central Conicoid: ellipsoid, hyperboloid, and paraboloid, their equations and geometrical interpretation.

Module 4: Tracing of curves (15 lectures)

Tracing of curves using concepts of derivatives, concavity-convexity, singular points (double point, cusp, and node), monotonicity of function, polar coordinates, and asymptotes.

List of books recommended for reference:

1. Loney S.L., *The Elements of Coordinate Geometry (Part I): Cartesian Coordinates* , MacMillan
2. P.K.Jain,Khalil Ahmad, *Analytic Geometry of three dimension*,2nd edition,Wiley Eastern Ltd. (1991)
3. Shanti Narayan, P.K.Mittal , *Differential Calculus* – S. Chand Publications.
4. Gibson C.G., *Elementary Euclidean Geometry: An undergraduate introduction*, Cambridge University Press.

Vocational Course

Course Title: PEDAGOGY OF MATHEMATICS

Course Code: UG-MAT-VOC1

Marks: 100

Credits: 4

Duration: 45 hours Theory, 30 hours practical

Course Objectives: To equip students with the knowledge, skills, and strategies necessary to effectively teach mathematics in a school setting.

Learning outcome: Upon completion of the course, students will be able to

CLO1 Understand the meaning, nature and scope of mathematics and its relation with other subjects.

CLO2 Write instructional objectives using Bloom's taxonomy

CLO3 Perform pedagogical analysis of various topics in mathematics

CLO4 Prepare lesson plans using various methods

CLO5 Select and use various methods and techniques to teach mathematics

Module 1: Nature and Scope of Teaching Mathematics (12 lectures)

Meaning, scope and nature of mathematics, History of Mathematics, Relation of mathematics with other school subjects, Values of Mathematics, Aims and objectives of teaching mathematics, Instructional objectives using Bloom taxonomy

Module 2: Pedagogical Analysis and Lesson Planning (12 lectures)

Meaning and importance of pedagogical analysis
Pedagogical Analysis of Arithmetic, Algebra, Geometry, Trigonometry and Menstruation
Lesson Planning: Need of a lesson plan, steps in lesson planning

Module 3: Methods and Techniques of Teaching Mathematics (21 lectures)

Methods of teaching: Lecture, demonstration, inductive-deductive, Heuristic, Analytic-synthetic, problem-solving, laboratory, project method
Techniques of teaching: Oral work, written work, drill, assignment, homework, review
Differentiated Teaching: Backward and Gifted students, causes and solutions.

Practicals:

1. Framing Course objectives using blooms taxonomy
2. Preparation of lesson plans for topics
3. Development of teaching aids for various topics in mathematics.
4. Book review of mathematics textbook
5. Prepare a PowerPoint presentation on some topic
6. Demonstrate the teaching methods
7. Prepare a diagnostic test for various topics

References:

1. R.G. Goel, Teaching of Mathematics, Lotus Press
2. A. James., Methods of teaching Mathematics, Neelkamal
3. Kline Morris, Mathematical Thought From Ancient to Modern Times, Oxford University Press
4. S. Krantz, How to teach Mathematics, American Mathematical Society
5. G. Polya, How to Solve It, Penguin UK
6. Sidhu Kulbir Singh., Teaching of Mathematics, Sterling Publishers Pvt. Ltd
7. J. Stillwell, Mathematics and its History, Springer
8. P.P Zubair., Teaching of Mathematics, Aph Publishing
9. M. Ediger, Essays on teaching mathematics, Discovery Publishing Pvt.Ltd

Semester V

DISCIPLINE-SPECIFIC CORE COURSES

Course Title: Calculus of Several Variables
Course Code: UG-MAT-301
Semester: V
Credits: 4
Marks: 100
Duration: 60 hours

Course Prerequisites: Basic knowledge of Real Analysis, Mathematical Analysis and Coordinate Geometry

Course Objectives
To introduce students to the concepts of multivariate calculus, focusing on the continuity, differentiation, and integration of functions of several variables. The course aims to provide a solid foundation for applying these concepts to visualize and analyze lines, curves, and surfaces in $\mathbb{R}^3$

Course Learning Outcomes
Upon completion of the course, the student will be able to:
CLO1: Understand and apply the concepts of neighborhoods, open sets, and limits in $\mathbb{R}^2$and $\mathbb{R}^3$
CLO2: Compute and interpret directional and partial derivatives, apply Taylor's theorem, and use the Lagrange multiplier method for optimization problems.
CLO3: Analyze the differentiability of functions, apply the total derivative, and use the Jacobian matrix along with the Implicit and Inverse Function Theorems.
CLO4: Perform integration over lines and regions, and calculate volumes and surface areas using double integrals.

Course Content

Module I: Introduction to Functions of Several Variables (15 Hours)
Neighbourhoods of a point in $\mathbb{R}^n$
Open sets in $\mathbb{R}^2$and $\mathbb{R}^3$
Limit points of a set, cluster points of a set, interior of a set
Sequences in $\mathbb{R}^2$and $\mathbb{R}^3$
Limit of sequences,
Limits and continuity of functions from $\mathbb{R}^2$ to $\mathbb{R}$
Examples and graphs of functions in several variables

Module II: Differentiability (18 Hours)
Partial derivatives, their geometrical interpretation.
Higher-order partial derivatives and equality of mixed partial derivatives.
Directional derivatives
Differentiability of functions of two variables.
Sufficient conditions for differentiability.

Total derivative and chain rule.
Jacobian matrix.

Module III: Important theorems on Differentiability (12 Hours)
Implicit and Inverse Function Theorems.
Mean Value Theorem (MVT) for functions of several variables.
Taylor's theorem and applications of partial derivatives.
Optimization problems: Maxima, minima, saddle points, and the Lagrange multiplier method.

Module IV: Integration of Multivariable Functions (15 Hours)
Line integrals and the fundamental theorem of calculus for multivariable functions.
Double integrals over rectangles and bounded regions.
Iterated integration and statement of Fubinis theorem
Calculating volumes and surface areas of simple geometrical objects.
Introduction to triple integration

List of Books Recommended for Reference

Mandatory Reading:

1. Hass, J., Heil, C., & Weir, M. D. (2018). *Thomas' calculus* (14th ed.). Pearson.
2. Ghorpade, S. R., & Limaye, B. V. (2010). *A course in multivariable calculus and analysis* (1st ed.). Springer.

Supplementary Reading:

1. Anton, H., Bivens, I. C., & Davis, S. (2016). *Calculus* (11th ed.). Wiley.
2. Apostol, T. M. (2007). *Calculus: Volume II* (2nd ed.). Wiley India.
3. Fleming, W. H. (1987). *Functions of several variables* (2nd ed.). Springer.

Course Title: Graph Theory
Course Code: UG-MAT-302
Semester: V
Credits: 4
Marks: 100
Duration: 60 hours
Course Objectives
To introduce students to the fundamental concepts of discrete graphs, their properties, types, and applications. The course aims to develop student's skills in analyzing graph structures and solving real-world problems using graph theory techniques.

Course Learning Outcomes
Upon completion of the course, the student will be able to:
CLO1: Identify and describe different types of graphs and their properties
CLO2: Analyze walks, paths, and cycles in graphs, and apply these concepts to various problems
CLO3: Understand graph connectivity, cut-points and blocks, and apply these concepts to solve connectivity problems.

CLO4: Understand trees and algorithms for finding minimum spanning trees and shortest paths, and apply these algorithms to practical problems.
CLO5: Investigate planarity, Euler's formula, and the representation of planar graphs, and the proof of the five-color theorem.
CLO6: Use graph coloring techniques, like vertex and edge coloring.

Course Content

Module I: Introduction to Graphs **(10 Hours)**
Introduction to discrete mathematical models.
The Konigsberg Bridges problem and Euler's solution.
Definitions and types of graphs: complete graphs, directed graphs, bipartite graphs, multigraphs.
Representation of graphs: adjacency matrix, incidence matrix.
Degree of a vertex: fundamental theorems
Operations on graphs: subgraphs, union, intersection, Cartesian product.
Isomorphisms in graphs
Special graphs: Petersen graphs, Herschel's Graphs.

Module II: Walks, Paths, and Cycles **(15 Hours)**
Definitions and properties of walks, paths, and cycles.
Distance and weighted distance, radius and diameter of a graph.
Eccentricity of a vertex.
Dijkstra's Algorithm for shortest paths.
Eulerian trails, Eulerian graphs, Hamiltonian cycles, Hamilton graphs, results
Application: Chinese Postman Problem, Traveling Salesman Problem.

Module III: Connectivity, Trees, and Algorithms **(20 Hours)**
Connectivity, cut-points, and blocks in a graph.
Definitions and properties of trees.
Spanning trees
Breadth-First Search Algorithm, Depth-First-Search Algorithm
Kruskal's Algorithm for minimum spanning trees, Prim's Algorithm for minimum spanning trees.

Module IV: Planarity and Colouring **(15 Hours)**
Planar graphs.
Maps and planar graphs.
Euler's formula
Representations and crossing number of graphs.
Vertex coloring, chromatic number of a graph, chromatic polynomial and its properties.
Proof of the five-color theorem for planar graphs.
Edge coloring of graphs.

List of Books Recommended for Reference

Mandatory Reading:
1. Chartrand, G., & Zhang, P. (2004). *Introduction to graph theory* (Illustrated ed.). McGraw-Hill.

Supplementary Reading:

1. Wallis, W. D. (2007). *A beginner's guide to graph theory* (2nd ed.). Birkhäuser.
2. West, D. B. (2001). *Introduction to graph theory* (2nd ed.). Prentice Hall of India.
3. Harary, F. (2001). *Graph theory*. Narosa Publishing House.
4. Balakrishnan, V. K. (1997). *Graph theory* (Schaum's outline series). McGraw Hill India.

Course Title: Advanced Analysis
Course Code: UG-MAT-303
Semester: V
Marks: 100
Credits: 4
Duration: 60 Hours

Course Prerequisites: Basic knowledge of Real Analysis and Mathematical Analysis

Course Objectives:
To introduce students to advanced methods for approximating continuous functions and differentiable functions, focusing on the analysis of sequences and series of functions, and the polynomial representation of functions.

Course Learning Outcomes
Upon completion of the course, the student will be able to:
CLO1: Analyze sequences and series of functions, their convergence, properties and related theorems.
CLO2: Apply techniques to approximate continuous functions as polynomials.
CLO3: Utilize special functions (exponential, logarithmic, and trigonometric)
CLO4: Understand and apply advanced topics such as continuity, gauges, δ-fine partitions, and approximation theorems including Weierstrass approximation and Dini's theorem.

Course Content

Module 1: Sequence of Functions **(15 Hours)**
Revision of Sequences of real numbers
Sequence of functions
Convergence and uniform convergence of sequence of functions
Continuity of limit of a sequence of functions, differentiability of limit of a sequence of functions, integrability of limit of a sequence of functions

Module 2: Advanced Approximation Techniques **(18 Hours)**
Gauges, δ-fine partitions and step functions.
Derivative of inverse functions- inverse function theoren
Weierstrass approximation theorem (using Bernstein polynomials).
Dini's theorem.

Module 3: Series of Functions **(15 Hours)**

Convergence and uniform convergence of series of functions
Power series and their radius of convergence, circle of convergence
Cauchy-Hadamard theorem.
Differentiation and uniqueness theorem of power series

Module 4: Special Functions **(12 Hours)**

Exponential functions, logarithmic functions, trigonometric functions, inverse trigonometric functions (differentiability and other results involved in special functions)

List of Books Recommended for Reference

Mandatory Reading:

1. Bartle, R. G., & Sherbert, D. R. (2011). *Introduction to real analysis* (4th ed.). Wiley.

Supplementary Reading:

1. Pugh, C. C. (2016). *Real mathematical analysis* (2nd ed.). Springer.
2. Kumaresan, S., & Kumar, A. (2014). *A basic course in real analysis* (1st ed.). CRC Press.
3. Berberian, S. K. (2012). *A first course in real analysis* (1st ed.). Springer.
4. Somasundaram, P. (1996). *Mathematical analysis*. Narosa Publishing House.
5. Rudin, W. (1976). *Principles of mathematical analysis* (3rd ed.). Tata McGraw-Hill.

VOCATIONAL COURSE

Course Title: Probability and Statistics (Theory)
Course Code: UG-MAT-VOC2
Semester: V
Credits: 4
Marks:75
Duration: 45

Course Objective:

To equip students with a foundational understanding of probability and statistics, enabling them to apply statistical methods and software tools to analyze data and make informed decisions.

Course Learning Outcomes (CLOs):

Upon successful completion of this course, students will be able to:

CLO1: Apply fundamental concepts of probability to solve real-world problems.

CLO2: Analyze data using statistical measures such as central tendency and dispersion.

CLO3: Understand and apply various probability distributions in practical situations.

CLO4: Conduct hypothesis testing and interpret results for decision-making.

CLO5: Use statistical software to perform data analysis and solve statistical problems.

Course Content:

Module 1: Descriptive Statistics and Data Analysis **(15 Hours)**
Data Visualization: Bar Graphs, Pie Charts, Histograms
Measures of Central Tendency: Mean, Median, Mode
Measures of Dispersion: Range, Variance, Standard Deviation
Correlation and Simple Linear Regression
Introduction to Statistical Software for Data Analysis (Excel, R, Python)

Module 2: Probability Theory and Random Variables **(15 Hours)**
Introduction to Probability: Classical, Relative Frequency, and Axiomatic Definitions Conditional Probability and Bayes' Theorem
Random Variables: Discrete and Continuous
Probability Distributions: Binomial, Poisson, and Normal
Expected Value and Variance of Random Variables

Module 3: Inferential Statistics and Hypothesis Testing **(15 Hours)**
Sampling Methods and Sampling Distributions
Hypothesis Testing: Null hypothesis and Alternative Hypotheses, p-values, Errors
t-test, z-test, Chi-square Test, ANNOVA

Course Title : Probability and Statistics (Practical)
Course Code: UG-MAT-VOC2
Semester : V
Credits : 01
Marks : 25
Duration : 30

List of Practicals:

1. Data Collection and Organization: Collect and organize data using tabulation methods. (2hrs)
2. Data Visualization: Create bar graphs, pie charts, and histograms to visualize data. (2hrs)
3. Descriptive Statistics: Calculate and interpret mean, median, mode, variance, and standard deviation.(2hrs)
4. Correlation and Regression Analysis: Perform correlation and simple linear regression analysis.(2hrs)
5. Probability Distributions: Fit and analyze Binomial, Poisson, and Normal distributions.(4hrs)
6. Hypothesis Testing: Conduct t-tests and z-tests on given datasets.(4hrs)
7. Chi-square Test : Conduct a Chi-square test for independence on categorical data.(2hrs)
8. Analyze a real-world dataset, apply statistical tools, and present results.(4hrs)
9. Simulation of Random Variables(2hrs)
10. Work on a case study to apply hypothesis testing in a practical scenario.(6hrs)

List of Books Recommended for Reference

Mandatory Reading:

1. Gupta, S. P., & Kapoor, V. K. (2020). *Fundamentals of mathematical statistics* (12th ed.). Sultan Chand & Sons.

Supplementary Reading:

1. Devore, J. L. (2015). *Probability and statistics for engineering and the sciences* (9th ed.). Cengage Learning
2. Ross, S. M. (2014). *A first course in probability* (9th ed.). Pearson.

Semester VI
DISCIPLINE-SPECIFIC CORE COURSE

Course Title: Vector Analysis
Course Code: UG-MAT-304
Semester: VI
Credits: 4
Marks: 100
Duration: 60 hours

Prerequisite Courses: Basic knowledge of coordinate geometry and calculus of several variables

Course Objectives:
To introduce students to the representation and manipulation of vectors in geometry, and to explore vector operations, vector calculus, and their applications in science and engineering.

Course Learning Outcomes
Upon completion of the course, the student will be able to:
CLO1: Understand and apply the fundamental operations of vectors
CLO2: Analyze vector-valued and scalar-valued functions in $\mathbb{R}^3$ using concepts like gradient, divergence, and curl.
CLO3: Apply the fundamental theorems of vector calculus such as Green's, Stokes', and Gauss' theorems, to solve physical and geometrical problems.
CLO4: Compute line, surface, and volume integrals and use them in real-world applications.
CLO5: Understand the geometric properties of curves in $\mathbb{R}^3$, such as curvature, torsion, and related concepts.

Course Content:

Module I: Introduction to Vectors **(10 hours)**
Revision of basic vector concepts: dot product, cross product, scalar triple product, and vector triple product.
Geometrical interpretation of vector operations.
Vector equations of geometrical objects, orthogonal vectors.

Module II: Vector and Scalar Fields in $\mathbb{R}^3$ **(20 hours)**
Vector-valued functions (vector fields) and scalar-valued functions (scalar fields).
Concepts of curves, planes, and surfaces in $\mathbb{R}^3$
Continuous, smooth, and regular objects in $\mathbb{R}^3$
Gradient, Divergence, and Curl: definitions, properties, and physical interpretations.

Irrotational and solenoidal vector fields.

Module III: Theory of Curves in $\mathbb{R}^3$ **(10 hours)**
Theory of curves: unit speed curves, tangent, normal, and binormal vectors.
Concepts of curvature and torsion.
Frenet-Serret formulae.
Evolutes and involutes.

Module IV: Vector Calculus Theorems **(20 hours)**
Line integrals, surface integrals, and volume integrals.
Calculation of arc lengths, surface areas, and volumes of simple objects.
Green's theorem, Stokes' theorem, Gauss' theorem, and Green's formulas: statement, proofs, and applications.

List of Books Recommended for Reference

Mandatory Reading:

1. Davis, H. F., & Snider, A. D. (1995). *Introduction to vector analysis* (6th ed.). Allyn & Bacon.

Supplementary Reading:

1. Marsden, J. E., & Tromba, A. (2012). *Vector calculus* (7th ed.). W. H. Freeman Publishers.
2. Kreyszig, E. (2011). *Advanced engineering mathematics* (10th ed.). Wiley India.
3. Spiegel, M. R. (1959). *Vector analysis* (Schaum's outline series). McGraw Hill.

Course Title: Complex Analysis
Course Code: UG-MAT-305
Semester: VI
Credits: 4
Marks: 100
Duration: 60 hours

Prerequisite Courses: Basic knowledge of Real Analysis, Mathematical Analysis and Calculus of Several Variables

Course Objectives
To provide students with a comprehensive understanding of complex numbers, complex functions, and the techniques of differentiation and integration of complex valued functions, building a foundation for further study in mathematical analysis.

Course Learning Outcomes
Upon completion of the course, the student will be able to:
CLO1: Understand the algebraic properties and geometric interpretation of complex numbers.
CLO2: Analyze the differentiability and continuity of functions of complex variables and apply the Cauchy-Riemann equations.
CLO3: Explain elementary complex functions such as exponentials, logarithms, and trigonometric functions.

CLO4: Perform contour integration and apply the Cauchy Integral Theorem and related results.
CLO5: Use the residue theorem to evaluate integrals and handle singularities of complex functions.

Course Content

Module I: Complex Numbers and Analytic Functions (20 Hours)
Algebraic properties of complex numbers
Argand diagram, exponential form, polar coordinates
Modulus, triangle inequality, metric properties,
Connectedness of regions.
Limits, continuity and differentiability of functions of complex variables
Analytic functions, algebra of analytic functions, Cauchy-Riemann equations, sufficient conditions for analyticity, harmonic functions.

Module II: Elementary Functions (10 Hours)
Exponential and logarithmic functions, their branches.
Trigonometric functions and hyperbolic functions.
Inverse trignometric functions and inverse hyperbolic functions.
Complex exponents and roots.

Module III: Contour Integration and Series (15 Hours)
Contours, contour integrals, Cauchy-Goursat theorem, simply connected domains, Cauchy's integral formula, higher derivatives of analytic functions, Liouville's theorem, fundamental theorem of algebra, maximum modulus principle.
Convergence of series, Taylor series, Laurent series.

Module IV: Residue Theory and Applications (15 Hours)
Singularities of a function: poles, essential singularities, removable singularities
Residues at poles and their computation.
Cauchy residue theorem and its applications.

List of Books Recommended for Reference

Mandatory Reading:

1. Churchill, R. V., & Brown, J. W. (2009). *Complex variables and applications* (8th ed.). McGraw Hill.

Supplementary Reading:

1. Spiegel, M. R., & Lipschutz, S. (2009). *Complex variable* (Schaum's outline series). McGraw Hill.
2. Shastri, A. R. (2007). *Complex analysis*. Laxmi Publications.
3. Ponnusamy, S., & Silverman, H. (2006). *Complex variables with applications*. Birkhäuser.
4. Ahlfors, L. V. (1979). *Complex analysis* (3rd ed.). McGraw Hill.

Course Title: Metric Spaces

Course Code: UG-MAT-306
Semester: VI
Credits: 4
Marks: 100
Duration: 60 hours

Prerequisite Courses: Basic knowledge of Real Analysis

Course Objectives

To introduce students to various concepts of distance in abstract mathematical settings and to explore the analytical structures and properties that arise from these different metrics, enhancing their understanding of Euclidean analysis.

Course Learning Outcomes

Upon completion of the course, the student will be able to:
CLO1: Understand the fundamental concepts and terminologies associated with metric spaces.
CLO2: Explore the geometric properties and structure of different metrics and subspaces.
CLO3: Analyze the connectedness and compactness properties of metric spaces.
CLO4: Apply the concepts of continuity of functions on metric spaces and their properties.

Course Content

Module I: Introduction to Metric Spaces and Basic Terminologies (15 Hours)

Definition and examples of metric spaces.
Terminologies: neighborhood, open ball, open sets and closed sets, interior points, exterior points , limit points, isolated points, cluster points, closure of a set, interior of a set, boundary of sets.
Dense sets, bounded sets, diameter of a set, distance between sets, and distance from a point to a set.
Results involving these concepts.

Module II: Subspaces, Sequences, and Completeness (15 Hours)

Equivalence of metrics and geometry with different metrics.
Subspaces of a metric space and results related to subspaces.
Sequences in a metric space, convergence, Cauchy sequences.
Complete metric spaces, completion of a metric space(only statement)

Module III: Connectedness and Compactness (20 Hours)

Separated sets, connected sets, connected components, and results on connectedness in metric spaces.
Compact metric spaces, open cover, finite cover, sequential compactness, one-point compactification.

Module IV: Functions on Metric Spaces (10 Hours)

Continuous functions (maps) on metric spaces and their equivalent definitions.
Invariance of compactness, completeness, and connectedness under continuous maps.
Open and closed maps and their basic properties.

List of Books Recommended for Reference

Mandatory Reading:

1. Copson, E. T. (1988). *Metric spaces*. Cambridge University Press.

Supplementary Reading:

1. Shirali, S., & Vasudeva, H. L. (2006). *Metric spaces*. Springer.
2. Kumaresan, S. (2005). *Topology of metric spaces* (2nd Edition). Narosa Publishing House.
3. Simmons, G. F. (1963). *Introduction to topology and modern analysis*. McGraw Hill.

Course Title: Differential Equations-II
Course Code: UG-MAT-307
Semester: VI
Credits: 4
Marks: 100
Duration: 60 hours

Prerequisite Courses: Knowledge of 1st-order differential equations

Course Objectives

To introduce advanced techniques for solving ordinary differential equations and provide an introduction to partial differential equations (PDEs), equipping students with method-based problem-solving skills and analytical thinking.

Course Learning Outcomes

Upon completion of the course, the student will be able to:
CLO1: Solve ordinary differential equations using power series methods, and apply these to special functions.
CLO2: Understand and apply Laplace transforms to solve ordinary differential equations.
CLO3: Analyze systems of first-order ordinary differential equations with constant coefficients.
CLO4: Address boundary value problems and apply Sturm-Liouville theory to linear differential equations of higher order.

Course Content

Module I: Power Series Solutions of ordinary Differential Equations (20 Hours)

Series solution of first-order ordinary differential equations.
Series solution of second-order linear ordinary differential equations at ordinary points.
Regular singular points, Gauss hypergeometric equation, Bessel's function, and Legendre polynomials.

Module II: Laplace Transforms and Applications (15 Hours)

Definition and examples of Laplace transforms.
Derivatives and integrals of Laplace transforms.
Applications to ordinary differential equations and convolutions.

Module III: Systems of First-Order Differential Equations **(10 Hours)**

Homogeneous linear systems with constant coefficients.
Non-homogenous linear systems
Conversion of ordinary differential equations of second order to system of first-order linear differential equations and vice versa

Module IV: Boundary Value Problems **(15 Hours)**

Boundary value problems and Sturm-Liouville theorems.
Linear ordinary differential equations of higher order.

List of Books Recommended for Reference

Mandatory Reading:

1. Simmons,G.F.(1972). *Differential Equations with Application and Historical Notes*, McGraw Hill.

Supplementary Reading:

1. Boyce,W.E., and Di Prima,R.C.(2009), *Elementary Differential Equations and Boundary Value Problems*(9^{th} ed), Wiley India.
2. M. Tenenbaum and H. Pollard (1985), *Ordinary Differential Equations*, Dover.

VOCATIONAL COURSE

Course Title: Operations Research Techniques(Theory)
Course Code: UG-MAT-VOC3
Credits: 3
Marks:75
Duration: 45 Hours

Prerequisite Courses: Basic knowledge of Linear Algebra and Probability

Course Objectives:

To develop a comprehensive understanding of key optimization techniques and decision-making strategies and provide hands-on experience with solving complex problems using advanced operations research methods equipping students with practical skills in applying these techniques to real-world scenarios in business and industry.

Course Learning Outcomes:

Upon completion of the course, the student will be able to:
CLO1: Formulate and solve Linear Programming Problems (LPP) and Transportation/Assignment problems using the simplex method and other optimization techniques.
CLO2: Solve real-world business problems using Game Theory and transform strategic situations into optimization models.
CLO3: Implement inventory control strategies and optimize queuing systems for efficient business

operations.
CLO4: Apply simulation techniques such as Monte Carlo simulation to model and solve business problems involving uncertainty.

Course Content:

Module I: Linear Programming, Simplex Method, and Transportation Problems (15 hours)
Introduction to Linear Programming Problems:
Formulation and solving using the simplex method, Big M method and Two-Phase Simplex method.(considering multiple solutions, unboundedness, and infeasibility)
Dual of a Linear programming problem,(Only 2 variables)
Transportation Problems: Mathematical formulation, initial basic feasible solution using North West Corner Rule(NWCR), and Modified distribution method (MODI) method for optimal solutions.
Assignment Problems: Solving using the Hungarian method.

Module II: Game Theory (10 hours)
Introduction to game theory
Solving two-person zero-sum games.
Mixed strategy games and graphical solutions.
Converting Game Theory problems into Linear Programming Problems.

Module III: Inventory Control, Queueing Theory, and Simulation (20 hours)
Inventory Control: Economic Order Quantity (EOQ), deterministic inventory problems, and price breaks.
Queueing Theory: Elements of queuing systems, classification, queuing models, and cost optimization.
Simulation: Introduction to simulation models., Monte Carlo simulation and event-type simulation.

Course Title: Operation Research Techniques (Practical)
Course Code: UG-MAT-VOC3
Semester: VI
Credits: 01
Marks: 25
Duration: 30

List of Practicals:
1. Formulating LPP problems using real-life case studies.(4hrs)
2. Solving graphical LPP problems with optimization software.(4hrs)
3. Solving transportation and assignment problems with case studies.(2hrs)
4. Use of Excel or dedicated software to model real-life transportation issues.(4hrs)
5. Simulating competitive scenarios using game theory.(4hrs)
6. Modeling inventory control systems using EOQ and simulation.(4hrs)
7. Simulation of queuing and inventory systems using Monte Carlo techniques.(4hrs)
8. Generating random numbers and applying them to real-world queuing models.(4hrs)

List of books recommended for reference:

Mandatory Reading:

1. Swarup, K., Gupta, P. K., & Man Mohan. (2022). *Operations research* (19th ed.). Sultan Chand & Sons.

Supplementary Reading:

1. Hillier, F. S., & Lieberman, G. J. (2020). *Introduction to operations research* (11th ed.). McGraw-Hill.
2. Taha, H. A. (2017). *Operations research: An introduction* (10th ed.). Pearson.
3. Sharma, J. K. (2013). *Operations research: Theory and applications* (5th ed.). Macmillan Publishers India.
4. Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2010). *Linear programming and network flows* (4th ed.). Wiley.
5. Trivedi, K. S. (2002). *Probability and statistics with reliability, queuing, and computer science applications* (2nd ed.). Wiley.
6. Davis, M. D. (1997). *Game theory: A nontechnical introduction* (2nd ed.). Dover Publications.