Chowgule Education Society's
Parvatibai Chowgule College of Arts and Science
Autonomous
Accredited by NAAC with Grade 'A+'
Best Affiliated College-Goa University Silver Jubilee Year Award

MINUTES OF MEETING OF THE BOARD OF STUDIES IN MATHEMATICS HELD ON 25th September 2024

Vide Chowgule College notice F.133C/707 a meeting of this BOS was convened on 25th September 2024 at Parvatibai Chowgule College of Arts & Science, Margao – Goa. Since the number of members present represented the Quorum, the BOS began its proceedings.

Members present:

1. Ms. Danielle Monteiro
2. Dr. Chitra Mekoth
3. Ms. Chetali Damodar Naik
4. Dr. Mamta Kumari
5. Dr. Mailattu Kunhanandan
6. Dr. Tarkeshwar Singh

Member Absent with Intimation

1. Ms. Melisa Fernandes
2. Mrs. Dinit Danny
3. Ms. Aniksha Mayekar

Proceedings

The Chairperson welcomed the members of the Board of Studies (BOS). The Chairperson introduced and explained the agenda for the meeting and read out the minutes of the previous B.O.S meeting. The meeting continued taking up the following agenda.

Agenda Items:

1. To approve the UG syllabus for Semesters V & VI under NEP 2020.
2. Selection and Approval of courses for Major1 and Major2 (Double Major)
3. To discuss and explore the internship opportunities for the students.
4. To approve the Program Specific Outcomes for the three-year undergraduate degree honours Programme in mathematics.
5. A.O.B.

PART A: The BOS passed the resolutions as follows:

1. The UG syllabus for Semesters V & VI under NEP 2020 was approved after deliberation and minor changes suggested.
2. The list of courses for Major 1 and Major 2 (Double Major) were selected and approved.
3. The internship opportunities for students were discussed and listed.
4. The Program Specific Outcomes for the three-year undergraduate degree honors Programme in mathematics were revised and approved after discussion.

PART B: Important Points/ recommendations of BOS that require consideration/approval of the Academic Council:

1. To seek approval for the UG syllabus for Semesters V & VI under NEP 2020
2. To seek approval for the list of courses for Major 1 and Major 2 (Double Major)
3. To seek approval for the revised Program Specific Outcome (PSO 4)

The following members of the Board of Studies in Mathematics were present for the meeting.

1. Ms. Danielle Monteiro
2. Dr. Chitra Mekoth
3. Ms. Chetali Damodar Naik
4. Dr. Mamta Kumari
5. Dr. Mailattu Kunhanandan
6. Dr. Tarkeshwar Singh

Member Absent with Intimation

1. Ms. Melisa Fernandes
2. Mrs. Dinit Danny
3. Ms. Aniksha Mayekar

Dr. Chitra Mekoth
Member Secretary
Board of Studies

Ms. Danielle Monteiro
Chairperson
Board of Studies

Dated: 30/9/2024

PART C:The remarks of the Dean of the Faculty:-

a. The minutes are in order.
b. The minutes may be placed before the Academic Council with remark, if any.
c. Important points of the minutes which need clear policy decisions of the Academic Council to be recorded.

Date: 04.10.2024

Signature of the Dean:
(Faculty of Arts/Science)

Dr. Meghana Devli

PART D:The remarks of the Members Secretary of the Academic Council:-

a. The minutes are in order.
b. The minutes may be placed before the Academic Council with remark, if any.
c. Important points of the minutes which need clear policy decision of the Academic Council to be recorded.

Date: 07.10.2024

Signature of the Member Secretary
Academic Council

Mr. V.C. Kumaresh

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-304:** Vector Analysis	**UG-MAT-VOC3:** Operations Research Techniques				
	UG-MAT-305: Complex Analysis					
	UG-MAT-306: Metric Spaces					
	UG-MAT-307: 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

Annexure A

(To be implemented w.e.f. Acad. Year 2025 - 2026)

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.