



Anekant Education Society's
Tuljaram Chaturchand College of Arts, Science & Commerce,
Baramati
(Empowered Autonomous)

Three/Four Year Honours/Honours with Research B.Sc. Degree
Program in Mathematics
(Faculty of Science)

CBCS Syllabus
T.Y.B.Sc. (Mathematics)
For Department of Mathematics

NEP-2.0
Choice Based Credit System Syllabus
(2024 Pattern)

(As Per NEP-2020)

To be implemented from Academic Year 2026-27

Title of the Programme: B.Sc. (Mathematics)**Preamble**

AES's Tuljaram Chaturchand College has made the decision to change the syllabus of across various faculties from June, 2023 by incorporating the guidelines and provisions outlined in the National Education Policy (NEP), 2020. The NEP envisions making education more holistic and effective and to lay emphasis on the integration of general (academic) education, vocational education and experiential learning. The NEP introduces holistic and multidisciplinary education that would help to develop intellectual, scientific, social, physical, emotional, ethical and moral capacities of the students. The NEP 2020 envisages flexible curricular structures and learning based outcome approach for the development of the students. By establishing a nationally accepted and internationally comparable credit structure and courses framework, the NEP 2020 aims to promote educational excellence, facilitate seamless academic mobility, and enhance the global competitiveness of Indian students. It fosters a system where educational achievements can be recognized and valued not only within the country but also in the international arena, expanding opportunities and opening doors for students to pursue their aspirations on a global scale.

In response to the rapid advancements in science and technology and the evolving approaches in various domains of Mathematics and related subjects, the Board of Studies in Mathematics at Tuljaram Chaturchand College, Baramati - Pune, has developed the curriculum for the fifth semester of T.Y.B.Sc. (Mathematics), which goes beyond traditional academic boundaries. The syllabus is aligned with the NEP 2020 guidelines to ensure that students receive an education that prepares them for the challenges and opportunities of the 21st century. This syllabus has been designed under the framework of the Choice Based Credit System (CBCS), taking into consideration the guidelines set forth by the National Education Policy (NEP) 2020, LOCF (UGC), NCrf, NHEQF, Prof. R. D. Kulkarni's Report, Government of Maharashtra's General Resolution dated 20th April and 16th May 2023, and 13th March, 2024 and Circular of SPPU, Pune dated 31st May 2023.

A Mathematics degree equips students with the knowledge and skills necessary for a diverse range of fulfilling career paths. Graduates in Mathematics find opportunities in various fields, including Financial Planner, Market Research Analyst, Data Scientist, teaching, Insurance underwriter, operations research analyst, software developer, and many other domains. After graduating with a degree in mathematics, students can embark on a

multitude of rewarding and diverse career paths. The analytical and problem-solving skills honed during their studies equip them with a strong foundation for success in various fields. Many graduates choose to pursue careers in academia and research, where they can contribute to the advancement of mathematical knowledge through teaching, publishing papers, and conducting ground breaking research. Others may opt for careers in the financial sector, such as investment banking or actuarial science, utilizing their expertise in mathematical modelling and statistical analysis to make informed decisions and manage risks. Additionally, the field of data science offers abundant opportunities for mathematics graduates, as they possess the ability to extract meaningful insights from complex data sets and develop algorithms that drive innovation in industries like technology, healthcare, and marketing. Moreover, mathematics graduates can find fulfilling careers in engineering, cryptography, software development, and operations research, to name just a few areas where their mathematical skills are highly sought after. Overall, a degree in mathematics opens doors to a wide range of intellectually stimulating and financially rewarding professions, allowing graduates to make significant contributions to society and thrive in a rapidly evolving world.

Overall, revising the Mathematics syllabus in accordance with the NEP 2020 ensures that students receive an education that is relevant, comprehensive, and prepares them to navigate the dynamic and interconnected world of today. It equips them with the knowledge, skills, and competencies needed to contribute meaningfully to society and pursue their academic and professional goals in a rapidly changing global landscape.

Credit Distribution Structure as per NEP 2020 (for NEP 2.0 2024 Pattern)

Level/ Difficulty	Sem	Subject DSC-1				Subject DSC-2	Subject DSC-3	GE/OE	SEC	IKS	AEC	VEC	CC	Total
4.5/100	I	2(T)+2(P)				2(T)+2(P)	2(T)+ 2(P)	2(T)	2 (T/P)	2(T) (Generic)	2(T)	2(T)	--	22
	II	2(T)+2(P)				2(T)+2(P)	2(T)+2(P)	2(P)	2 (T/P)	--	2(T)	2(T)	2(T)	22
Exit option: Award of UG Certificate in Major with 44 credits and an additional 4 credits core NSQF course/Internship OR Continue with Major and Minor Continue option: Student will select one subject among the (subject 1, subject 2 and subject 3) as major and other as minor and third subject will be dropped.														
Level/ Difficulty	Sem	Credits Related to Major				Minor	--	GE/OE	SEC	IKS	AEC	VEC	CC	Total
		Major Core	Major Elective	VSC	FP/OJT/CEP /RP									
5.0/200	III	4(T)+2(P)	--	2 (T/P)	2(FP)	2(T)+2(P)	--	2(T)	--	2(T)	--	2(T)	22	
	IV	4(T)+2(P)	--	2 (T/P)	2(CEP)	2(T)+2(P)	--	2(P)	2 (T/P)	--	2(T)	--	2(T)	22
Exit option: Award of UG Diploma in Major and Minor with 88 credits and an additional 4credits core NSQF course/Internship OR Continue with Major and Minor														
5.5/300	V	8(T)+4(P)	2(T)+2(P)	2 (T/P)	2(FP/CEP)	2(T)	--	--	--	--	--	--	22	
	VI	8(T)+4(P)	2(T)+2(P)	2 (T/P)	4 (OJT)	--	--	--	--	--	--	--	22	
Total 3Years		44	8	8	10	18	8	8	6	4	8	4	6	132
Exit option: Award of UG Degree in Major with 132 credits OR Continue with Major and Minor														
6.0/400	VII	6(T)+4(P)	2(T)+2 (T/P)	--	4(RP)	4(RM)(T)	--	--	--	--	--	--	22	
	VIII	6(T)+4(P)	2(T)+2 (T/P)	--	6(RP)	--	--	--	--	--	--	--	22	
Total 4Years		64	16	8	22	22	8	8	6	4	8	4	6	176
Four Year UG Honours with Research Degree in Major and Minor with 176 credits														
6.0/400	VII	10(T)+4(P)	2(T)+2 (T/P)	--	--	4(RM) (T)	--	--	--	--	--	--	22	
	VIII	10(T)+4(P)	2(T)+2 (T/P)	--	4 (OJT)	--	--	--	--	--	--	--	22	
Total 4Years		72	16	8	14	22	8	8	6	4	8	4	6	176
Four Year UG Honours Degree in Major and Minor with 176 credits														
T = Theory P = Practical DSC = Discipline Specific Course OE = Open Elective SEC = Skill Enhancement Course IKS = Indian Knowledge System AEC = Ability Enhancement Course VEC = Value Education Course CC = Co-curricular Course VSC= Vocational Skill Course OJT= On Job Training CEP= Community Engagement Project FP= Field Project RP= Research Project														

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NEP-2.0

Course Structure for F.Y.B.Sc. (2024 Pattern as per NEP-2020)

Sem	Course Type	Course Code	Course Title	Theory / Practical	Credits
I	DSC-I (General)	-101-GEN		Theory	02
		-102-GEN		Practical	02
	DSC-II (General)	-101-GEN		Theory	02
		-102-GEN		Practical	02
	DSC-III (General)	MAT-101-GEN	Algebra and Calculus	Theory	02
		MAT-102-GEN	Algebra and Calculus Practical with Python	Practical	02
	Open Elective (OE)	MAT-103-OE	Basic Mathematics	Theory	02
	Skill Enhancement Course (SEC)	MAT-104-SEC	Scilab Software	Practical	02
	Ability Enhancement Course (AEC)	ENG-104-AEC		Theory	02
	Value Education Course (VEC)	ENV-105-VEC		Theory	02
Generic Indian Knowledge System (GIKS)	GEN-106-IKS		Theory	02	
Total Credits Semester-I					22
II	DSC-I (General)	-151-GEN		Theory	02
		-152-GEN		Practical	02
	DSC-II (General)	-151-GEN		Theory	02
		-152-GEN		Practical	02
	DSC-III (General)	MAT-151-GEN	Geometry and Differential Calculus	Theory	02
		MAT-152-GEN	Geometry and Differential Calculus Practical with Geogebra	Practical	02
	Open Elective (OE)	MAT -153-OE	Applied Mathematics	Practical	02
	Skill Enhancement Course (SEC)	MAT -154-SEC	Maxima Software	Practical	02
	Ability Enhancement Course (AEC)	ENG-154-AEC		Theory	02
	Value Education Course (VEC)	COS-155-VEC		Theory	02
Co-curricular Course (CC)	YOG/PES/CUL/NSS/NCC-156-CC	To be selected from the CC Basket	Theory	02	
Total Credits Semester-II					22
Cumulative Credits Semester I + Semester II					44

Course Structure for S.Y.B.Sc. Mathematics (2024 Pattern as per NEP-2020)

Sem	Course Type	Course Code	Course Title	Theory / Practical	Credits
III	Major Mandatory	MAT-201-MRM	Multivariable Calculus	Theory	2
	Major Mandatory	MAT-202-MRM	Laplace Transform	Theory	2
	Major Mandatory	MAT-203-MRM	Practical based on Multivariable Calculus and Laplace Transform	Practical	2
	Vocational Skill Course (VSC)	MAT-204-VSC	Practical based on Numerical Methods	Practical	2
	Field Project (FP)	MAT-205-FP	Field Project	Practical	2
	Minor	MAT-206-MN	Fundamentals of Linear Algebra	Theory	2
	Minor	MAT-207-MN	Practical based on Differential Equations	Practical	2
	Open Elective (OE)	MAT-208-OE	Fundamentals of Higher Mathematics	Theory	2
	Subject Specific Indian Knowledge System (IKS)	MAT-209-IKS	Vedic Mathematics	Theory	2
	Ability Enhancement Course (AEC)	MAR-210-AEC		Theory (Any One)	2
		HIN-210-AEC			
SAN-210-AEC					
Co-curricular Course (CC)	YOG/PES/CUL /NSS/NCC-211-CC	To be continued from Semester – II	Theory	2	
Total Credits Semester-III					22
IV	Major Mandatory	MAT-251-MRM	Vector Analysis	Theory	2
	Major Mandatory	MAT-252-MRM	Introduction to Linear Algebra	Theory	2
	Major Mandatory	MAT-253-MRM	Practical based on Vector Analysis and Linear Algebra	Practical	2
	Vocational Skill Course (VSC)	MAT-254-VSC	Set Theory and Logic	Theory	2
	Community Engagement Project (CEP)	MAT-255-CEP	Community Engagement Project	Practical	2
	Minor	MAT-256-MN	Multivariable Calculus	Theory	2
	Minor	MAT-257-MN	Practical based on Numerical Analysis	Practical	2
	Open Elective (OE)	MAT-258-OE	Basic Applications of Mathematics	Practical	2
	Skill Enhancement Course (SEC)	MAT-259-SEC	LaTeX Software	Practical	2
	Ability Enhancement Course (AEC)	MAR-260-AEC		Theory (Any One)	2
		HIN-260-AEC			
		SAN-260-AEC			
Co-curricular Course (CC)	YOG/PES/CUL /NSS/NCC-261-CC	To be continued from Semester – III	Theory	2	
Total Credits Semester-IV					22
Cumulative Credits Semester III + Semester IV					44

Course Structure for T.Y.B.Sc. Mathematics (2024 Pattern as per NEP-2020)

Sem	Course Type	Course Code	Course Title	Theory / Practical	Credits
V	Major Mandatory	MAT-301-MRM	Topology of Metric Spaces	Theory	2
	Major Mandatory	MAT-302-MRM	Real Analysis	Theory	2
	Major Mandatory	MAT-303-MRM	Group Theory	Theory	2
	Major Mandatory	MAT-304-MRM	Ordinary Differential Equations	Theory	2
	Major Mandatory	MAT-305-MRM	Practical based on Metric Spaces and Real Analysis	Practical	2
	Major Mandatory	MAT-306-MRM	Practical based on Group Theory and Differential Equations	Practical	2
	Major Elective	MAT-307-MJE (A)	Operations Research	Theory (Any One)	2
	Major Elective	MAT-307-MJE (B)	Graph Theory		
	Major Elective	MAT-308-MJE (A)	C Programming	Practical (Any One)	2
	Major Elective	MAT-308-MJE (B)	Practical based on Combinatorics		
	On-Job Training	MAT-309-OJT	On-Job Training	Practical	4
	Minor	MAT-310-MN	Basics of Abstract Algebra and Modern Analysis	Theory	2
Total Credits Semester-V					22
VI	Major Mandatory	MAT-351-MRM	Complex Analysis	Theory	2
	Major Mandatory	MAT-352-MRM	Lebesgue Integration	Theory	2
	Major Mandatory	MAT-353-MRM	Ring Theory	Theory	2
	Major Mandatory	MAT-354-MRM	Number Theory	Theory	2
	Major Mandatory	MAT-355-MRM	Practical based on Complex Analysis and Lebesgue Integration	Practical	2
	Major Mandatory	MAT-356-MRM	Practical based on Ring Theory and Number Theory	Practical	2
	Major Elective	MAT-357-MJE (A)	Computational Geometry	Theory (Any One)	2
	Major Elective	MAT-357-MJE (B)	Lattice Theory		
	Major Elective	MAT-358-MJE (A)	Python Programming	Practical (Any One)	2
	Major Elective	MAT-358-MJE (B)	Practical based on Cryptography		
	Vocational Skill Course (VSC)	MAT-359-VSC	Mathematics for Data Science	Theory	2
	Vocational Skill Course (VSC)	MAT-360-VSC	Mathematical Modeling	Practical	2
Field Project / CEP	MAT-361-FP	Field Project / CEP	Practical	2	
Total Credits Semester-VI					22
Cumulative Credits Semester V + Semester VI					44

Programme Specific Outcomes (PSOs)

PSO 1-Proficiency in Mathematical Concepts: Graduates will have a deep understanding of fundamental mathematical concepts and theories across various branches of mathematics, including calculus, algebra, geometry, probability, and statistics.

PSO 2-Problem-Solving Skills: Graduates will possess strong problem-solving skills and the ability to apply mathematical principles to real-world situations. They can analyze complex problems, develop logical reasoning, and devise creative strategies to find solutions.

PSO 3-Mathematical Modeling: Graduates will be proficient in mathematical modeling, which involves using mathematical techniques to describe and analyze real-world phenomena. They can formulate and solve mathematical models to address problems in diverse fields, including physics, economics, engineering, and social sciences.

PSO4-Computational and Analytical Skills: Graduates will be skilled in using computational tools and software, such as programming languages, statistical software, and mathematical modeling software. They can leverage these tools to perform numerical analysis, data visualization, and simulations.

PSO 5-Communication and Presentation: Graduates will possess effective communication skills, both written and oral, to convey complex mathematical ideas and results to both technical and non-technical audiences. They can present mathematical arguments, proofs, and findings in a clear and concise manner.

PSO 6-Research and Inquiry: Graduates will have the ability to engage in mathematical research and inquiry. They can critically evaluate existing mathematical theories, develop new mathematical models, and contribute to the advancement of mathematical knowledge through independent research or collaborative projects.

PSO 7-Interdisciplinary Collaboration: Graduates will be adept at collaborating with professionals from other disciplines, such as scientists, engineers, economists, and computer scientists. They can effectively communicate and work in multidisciplinary teams to solve complex problems that require mathematical expertise.

PSO 8-Lifelong Learning: Graduates will have developed a strong foundation for lifelong learning in mathematics. They will have the skills to stay abreast of new developments in the field, adapt to emerging technologies and methodologies, and continue their professional growth through self-directed study or advanced academic pursuits.

PSO 9-Advanced Mathematical Techniques: Graduates will have a command of advanced mathematical techniques, such as differential equations, mathematical analysis, linear algebra, number theory, and optimization. They can apply these advanced mathematical tools to solve complex problems and contribute to specialized areas of research.

PSO 10-Mathematical Software Development: Graduates will possess programming skills and the ability to develop mathematical software or algorithms. They can design, implement, and optimize software applications that facilitate mathematical calculations, simulations, data analysis, and modeling.

PSO 11-Mathematical Education and Teaching: Graduates interested in pursuing a career in education will have the necessary skills to teach mathematics at various levels. They can design and deliver effective lessons, develop curriculum materials, and assess student progress in mathematics. They can also inspire and motivate students to develop an appreciation for the subject.

PSO 12-Mathematical Finance and Risk Analysis: Graduates with an interest in finance and economics will have specialized knowledge in mathematical finance and risk analysis. They can apply mathematical models, stochastic calculus, and statistical methods to analyze financial markets, manage investment portfolios, assess risk, and make informed financial decisions.

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2024 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Mandatory (Theory)
Course Name	: Topology of Metric Spaces
Course Code	: MAT-301-MRM
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To introduce the fundamental concept of a metric space as a generalization of Euclidean space and to familiarize students with key examples like normed linear and sequence spaces.
2. To develop an understanding of the topological structure of metric spaces, including open and closed sets, limit points, closure, and their properties.
3. To analyze the concepts of convergence, limits, and continuity in the abstract setting of metric spaces, reinforcing them with the rigorous ε - δ definition.
4. To equip students with the concept of completeness, Cauchy sequences, and the powerful Banach Contraction Principle along with its applications.
5. To explore the central idea of compactness, its various characterizations, and its profound implications for continuous functions.
6. To study the properties of connected and path-connected spaces, understanding their role in characterizing the continuity of functions.
7. To enable students to distinguish between and interrelate the core topological properties of metric spaces: completeness, compactness, and connectedness.

Course Outcomes:

CO1: Students will be able to define a metric space and identify whether a given function is a valid metric, and construct examples in Euclidean, normed, and sequence spaces.

CO2: Students will be able to determine whether a subset of a metric space is open, closed, or bounded, and compute its closure, interior, and boundary.

CO3: Students will be able to analyze sequences in metric spaces for convergence and apply the ε - δ definition to prove the continuity of functions between metric spaces.

CO4: Students will be able to test sequences for the Cauchy property and determine if a metric space is complete; apply the Banach Contraction Principle to find fixed points.

CO5: Students will be able to identify compact sets using various characterizations and demonstrate how compactness preserves key properties like boundedness and uniform continuity under continuous maps.

CO6: Students will be able to distinguish between connected and path-connected spaces and prove basic properties, such as the continuous image of a connected set is connected.

CO7: Students will be able to compare and contrast the fundamental properties of completeness, compactness, and connectedness, illustrating their relationships and differences with concrete examples.

Topics and Learning Points		Teaching Hours
Unit 1: Metric Spaces		07
1.1 Introduction: The Euclidean spaces, Balls and Bounded sets		
1.2 Convergence in Metric Spaces		
1.3 Normed Linear Spaces		
1.4 Sequence Spaces		
Unit 2: Topology		07
2.1 Open and Closed Sets		
2.2 Limit Points and Isolated Points		
2.3 Closure and Boundaries		
2.4 Limits and Continuity		
Unit 3: Completeness		06
3.1 Introduction		
3.2 Banach Contraction Principle		
3.3 Characterization of Completeness		
3.4 Completion of Metric Spaces		
Unit 4: Compactness		05
4.1 Compact and Closed Sets		
4.2 Characterization of Compact Sets		
4.3 Continuity and Compactness		
4.4 Lipschitz Continuity		
Unit 5: Connectedness		05
5.1 Path Connectedness		
5.2 Connected Sets		
5.3 Components		

Text Book:

Surinder Pal Singh Kainth, *A Comprehensive Textbook on Metric Spaces*, Springer.

Unit 1: Chapter 2, **Unit 2:** Chapter 3, **Unit 3:** Chapter 4,

Unit 4: Chapter 5, **Unit 5:** Chapter 6.

Reference Books:

1. Micheal O'Searcoid, *Metric Spaces*, Springer.
2. Satish Shirali and Harkrishan L. Vasudeva, *Metric Spaces*, Springer
3. James R. Munkres, *Topology*, Pearson.
4. Pawan K. Jain and Khalil Ahmad, *Metric Spaces*, Narosa Publishing House.
5. Richard R. Goldberg, *Methods of Real Analysis*, Oxford & IBH Publishing Co. Pvt. Ltd.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	2	2	3	3	3	2	2
PO03	1	1	1	2	1	1	1
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	2	2	3
PO07	2	2	3	3	3	2	3
PO08	2	2	3	3	3	2	3
PO09	1	1	2	2	2	1	1
PO10	1	1	1	1	1	1	1
PO11	1	1	1	1	1	1	1
PO12	2	2	3	3	3	2	3
PO13	1	1	1	1	1	1	1

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All course outcomes (CO1–CO7) strongly contribute to PO1. The course develops rigorous understanding of metric spaces, including definitions, topological properties (open, closed, compact, connected sets), convergence, completeness, and fixed point theory. Students gain deep conceptual clarity and theoretical foundation in advanced analysis. Hence, the contribution is strong.

PO2: Practical, Professional, and Procedural Knowledge

CO3, CO4, and CO5 strongly support PO2 as students apply ϵ - δ arguments, test Cauchy sequences, verify completeness, and use the Banach Contraction Principle. These involve systematic mathematical procedures and logical steps. CO1, CO2, CO6, and CO7 moderately contribute as they involve structured verification of definitions and properties. Hence, the contribution ranges from moderate to strong.

PO3: Entrepreneurial Mind-set and Knowledge

The course is primarily theoretical; therefore, its direct contribution is limited. However, CO4 (fixed point theory) provides foundational knowledge useful in optimization, modeling, and applied problem-solving domains relevant to entrepreneurship. Thus, the contribution is weak to moderate.

PO4: Specialized Skills and Competencies

All COs strongly contribute to PO4. The course builds specialized competencies in abstract reasoning, proof construction, logical rigor, and higher mathematical thinking. Understanding

compactness, completeness, and connectedness enhances advanced analytical capability. Hence, the contribution is strong.

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

CO1–CO7 directly enhances analytical reasoning and mathematical problem-solving skills. Students analyse structures, construct proofs, compare properties, and apply theorems in different contexts. The ability to distinguish between completeness, compactness, and connectedness particularly strengthens higher-order reasoning. Therefore, the contribution is strong.

PO6: Communication Skills and Collaboration

Students are required to write rigorous proofs, explain definitions, justify logical arguments, and present mathematical reasoning clearly. CO7 especially enhances conceptual articulation by comparing core properties. Thus, the contribution is moderate to strong in terms of mathematical communication.

PO7: Research-Related Skills

CO3, CO4, CO5, and CO7 strongly support research skills by developing theorem-proving ability, logical deduction, abstraction, and exploration of mathematical structures. These are foundational skills for higher research in analysis and topology. Hence, the contribution is strong, while introductory concepts (CO1, CO2, CO6) contribute moderately.

PO8: Learning How to Learn Skills

The abstract nature of the subject encourages independent thinking, self-study, and exploration of advanced mathematical texts. Students learn how to approach new definitions and construct proofs independently. CO3–CO7 especially promote self-directed learning. Thus, the contribution is moderate to strong.

PO9: Digital and Technological Skills

While primarily theoretical, the concepts of metric spaces, convergence, and fixed point theory are foundational in computational mathematics, numerical analysis, and applied modeling. Hence, CO3–CO5 moderately support digital competency, though overall contribution remains moderate.

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course contributes indirectly by promoting universal logical reasoning and objective thinking, which transcends cultural boundaries. However, direct linkage is minimal. Hence, the contribution is weak.

PO11: Value Inculcation and Environmental Awareness

The subject promotes intellectual honesty, precision, discipline, and ethical academic practice in proof writing. However, it does not directly address environmental themes. Therefore, the contribution is weak but foundational in value-based academic rigor.

PO12: Autonomy, Responsibility, and Accountability

Students develop independent proof-writing ability and logical accountability in mathematical arguments. CO3, CO4, CO5, and CO7 especially demand autonomous reasoning and justification of results. Hence, the contribution is strong.

PO13: Community Engagement and Service

The course has limited direct societal engagement. However, strong analytical skills developed through this subject enable students to contribute effectively in academic and professional communities. Therefore, the contribution is weak to indirect.

CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics (2024 Pattern)

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Mandatory (Theory)
Course Name	: Real Analysis
Course Code	: MAT-302-MRM
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To establish a rigorous understanding of the behavior of sequences of real numbers, including convergence, monotonicity, and the fundamental concept of Cauchy sequences.
2. To extend the concept of convergence from sequences to infinite series, equipping students with various tests to analyze the convergence of series with non-negative and alternating terms.
3. To differentiate between absolute and conditional convergence, highlighting the subtle properties of conditionally convergent series.
4. To construct the theory of the Riemann integral rigorously, starting from the concepts of partitions, upper and lower sums, and sets of measure zero.
5. To explore the fundamental properties of the Riemann integral and establish the profound connection between integration and differentiation via the Fundamental Theorems of Calculus.
6. To generalize the integral to unbounded intervals and functions through improper integrals and develop tests for their convergence.
7. To introduce the Cauchy Principal Value as a method for assigning values to certain divergent improper integrals and understand its distinction from absolute convergence.

Course Outcomes:

CO1: Students will be able to analyze the convergence of a given sequence using definitions (ϵ - N) and theorems (monotone convergence), and compute its limit superior and limit inferior.

CO2: Students will be able to apply appropriate tests (e.g., Comparison, Integral, Ratio) to determine the convergence or divergence of series with non-negative terms.

CO3: Students will be able to distinguish between absolute and conditional convergence for series and utilize the Alternating Series Test to analyze series with mixed signs.

CO4: Students will be able to explain the formal definition of the Riemann integral based on partitions and Darboux sums and determine the integrability of a function, including over sets of measure zero.

CO5: Students will be able to employ the Fundamental Theorems of Calculus to evaluate definite integrals and prove basic properties of the Riemann integral.

CO6: Students will be able to classify different types of improper integrals and investigate their convergence (absolute or conditional) using relevant tests (e.g., Comparison, p -test).

CO7: Students will be able to calculate the Cauchy Principal Value for an improper integral and contrast its existence with the existence of the integral in the standard sense.

Topics and Learning Points		Teaching Hours
Unit 1: Sequences of Real Numbers		07
1.1 Basic definitions		
1.2 Convergence of sequences		
1.3 Bounded and monotone sequences		
1.4 Operations on sequences		
1.5 Limit superior and limit inferior		
1.6 Cauchy sequences		
Unit 2: Series of Real Numbers		07
2.1 Convergence of series		
2.2 Series with nonnegative terms		
2.3 Alternating series		
2.4 Conditional and absolute convergence		
2.5 Tests for absolute convergence		
2.6 The class l^2		
Unit 3: Riemann Integral		07
3.1 Sets of measure zero		
3.2 Definition of Riemann integral		
3.3 Existence of Riemann integral		
3.4 Properties of Riemann integral		
3.5 Fundamental theorems of calculus		
Unit 4: Improper Integrals		05
4.1 Types of improper integrals		
4.2 Convergence, conditional convergence and absolute convergence		
4.3 Tests for absolute convergence of improper integral		
4.4 Cauchy Principal Value (CPV)		

Text Book:

Richard R. Goldberg, *Methods of Real Analysis*, Oxford & IBH Publishing Co. Pvt. Ltd., Indian Edition.

Unit 1: Sections 2.1 to 2.10,

Unit 2: Sections 3.1 to 3.4, 3.6 and 3.10,

Unit 3: Sections 7.1 to 7.4 and 7.8

D. Somasundaram and B. Choudhary, *A first course in Mathematical Analysis*, Narosa Publishing House, 1997.

Unit 4: Sections 8.5

Reference Books:

1. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, CRC Press, Second Indian Reprint 2015.
2. D. Somasundaram and B. Choudhary, *A first course in Mathematical Analysis*, Narosa Publishing House, 1997.
3. Robert G. Bartle and Donald Sherbert, *Introduction to Real Analysis*, John Wiley and Sons, 3rd Edition.
4. Shantinarayan and Mittal, *A course of Mathematical Analysis*, S. Chand and Co., Revised Edition (2002).

5. S. C. Malik and Savita Arora, *Mathematical Analysis*, New Age International Publications, 3rd Edition (2008).

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	2	3	3	2
PO03	1	1	1	1	2	1	1
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	2	2	3
PO07	3	3	3	3	3	3	3
PO08	2	3	3	3	3	3	3
PO09	2	2	2	2	2	2	2
PO10	1	1	1	1	1	1	1
PO11	1	1	1	1	1	1	1
PO12	3	3	3	3	3	3	3
PO13	1	1	1	1	1	1	1

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs (CO1–CO7) strongly contribute to PO1 as the course develops deep theoretical understanding of sequences, series, convergence tests, Riemann integration, improper integrals, and Cauchy Principal Value. Students gain strong conceptual clarity and mathematical maturity. Hence, contribution is strong.

PO2: Practical, Professional, and Procedural Knowledge

CO1, CO2, CO3, CO5, and CO6 strongly support procedural knowledge through systematic application of convergence tests and Fundamental Theorems of Calculus. CO4 and CO7 moderately contribute as they involve theoretical explanations and conceptual analysis. Hence, contribution ranges from moderate to strong.

PO3: Entrepreneurial Mindset and Knowledge

The subject is theoretical in nature. However, CO5 (application of Fundamental Theorem of Calculus) has indirect application in economics, engineering, and optimization. Overall contribution remains weak with slight relevance in applied contexts.

PO4: Specialized Skills and Competencies

All COs strongly build advanced analytical and mathematical competencies. Students acquire specialized skills in rigorous proof writing, logical deduction, testing convergence, and integration theory. Hence, contribution is strong.

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

Every CO directly enhances problem-solving ability: CO1–CO3: Analytical evaluation of convergence. CO4–CO7: Logical analysis of integrability and improper integrals. The course significantly strengthens abstract reasoning. Hence, strong.

PO6: Communication Skills and Collaboration

Students must clearly explain convergence tests, justify integrability, and write formal mathematical proofs. CO7 especially requires conceptual comparison and explanation. Hence, contribution is moderate to strong (2–3).

PO7: Research-Related Skills

All COs strongly contribute to research skills by developing rigorous proof techniques, theorem application, limit analysis, and integral theory. These are foundational tools for higher research in real analysis and applied mathematics. Hence, strong (3).

PO8: Learning How to Learn Skills

The subject demands independent study, interpretation of definitions, and theorem-based reasoning. CO2–CO7 particularly enhance self-directed learning and analytical independence. Therefore, contribution is moderate to strong (2–3).

PO9: Digital and Technological Skills

Concepts of convergence, integration, and improper integrals are foundational in numerical methods, computational modeling, and data science. Although not directly software-based, theoretical foundation supports technological applications. Hence, moderate (2).

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course primarily develops logical and objective reasoning but has minimal direct cultural engagement. Therefore, contribution is weak (1).

PO11: Value Inculcation and Environmental Awareness

The course promotes academic integrity, logical precision, and disciplined reasoning, but has no direct environmental component. Hence, contribution is weak (1).

PO12: Autonomy, Responsibility, and Accountability

Students independently construct proofs, justify logical steps, and verify convergence rigorously. All COs strongly promote intellectual responsibility and autonomous reasoning. Hence, strong (3).

PO13: Community Engagement and Service

The subject has limited direct societal linkage. However, analytical skills gained can indirectly benefit academic and professional communities. Therefore, contribution is weak (1).

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2024 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Mandatory (Theory)
Course Name	: Group Theory
Course Code	: MAT-303-MRM
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To introduce the axiomatic structure of a group through concrete examples, with a special emphasis on symmetries (Dihedral groups) and permutations.
2. To develop the theory of finite groups, focusing on the concepts of the order of an element, subgroups, and the powerful Lagrange's Theorem with its consequences.
3. To provide a comprehensive understanding of cyclic groups, their structure, generators, and the Fundamental Theorem which classifies all subgroups of cyclic groups.
4. To analyze permutation groups in detail, building proficiency in cycle notation and understanding the classification of permutations into even and odd.
5. To establish the concept of a normal subgroup as the key object that enables the construction of quotient groups.
6. To explore the relationships between groups through homomorphisms and isomorphisms, culminating in the Fundamental Homomorphism Theorem.
7. To demonstrate Cayley's Theorem, revealing that every group is fundamentally isomorphic to a permutation group, unifying concrete and abstract perspectives.

Course Outcomes:

CO1: Students will be able to identify whether a given set with a binary operation forms a group and demonstrate understanding of basic group properties, such as the uniqueness of identity and inverses.

CO2: Students will be able to determine the order of any element in a group, apply subgroup tests to verify subsets are subgroups, and compute the center and centralizer of elements.

CO3: Students will be able to apply Lagrange's Theorem to deduce properties of finite groups and analyze the structure of cyclic groups, including finding all their generators.

CO4: Students will be able to express permutations using cycle notation, compute their products and orders, and classify them as even or odd.

CO5: Students will be able to prove whether a given subgroup is normal and explain its significance in the context of forming quotient groups.

CO6: Students will be able to define and construct group homomorphisms, determine if a homomorphism is an isomorphism, and apply the fundamental properties of isomorphisms.

CO7: Students will be able to illustrate Cayley's Theorem by finding an isomorphic copy of a finite group as a subgroup of a symmetric group.

Topics and Learning Points		Teaching Hours
Unit 1: Introduction to Groups		04
1.1 Symmetries of square and the Dihedral groups		
1.2 Definition and examples of groups		
1.3 Elementary properties of groups		
Unit 2: Finite Groups and Subgroups		06
2.1 Order of group, Order of elements		
2.2 Subgroup Tests and examples		
2.3 Center of a group and Centralizer of element		
2.4 Cosets: definition and properties		
2.5 Lagrange's theorem and corollary		
Unit 3: Cyclic Groups		05
3.1 Properties of cyclic groups and examples		
3.2 Order of finite cyclic groups		
3.3 Generators of finite cyclic groups		
3.4 Fundamental theorem of Cyclic Groups		
Unit 4: Permutation Groups		05
4.1 Definition and examples		
4.2 Permutation on S_n , detail discussion of S_3		
4.3 Properties and theorems on permutation		
4.4 Even odd permutation		
Unit 5: Normal Subgroup		04
5.1 Definition		
5.2 Theorems on Normal subgroup		
Unit 6: Homomorphism and Isomorphism's		06
6.1 Homomorphism and fundamental theorem of homomorphism		
6.2 Group isomorphism's		
6.3 Cayley's Theorem		
6.4 Properties of isomorphism		
6.5 Automorphisms		

Text Book:

Joseph Gallian, *Contemporary Abstract Algebra*, Narosa Publishing House.

Unit 1: Chapter 1 & 2, **Unit 2:** Chapter 3, **Unit 3:** Chapter 4,

Unit 4: Chapter 5, **Unit 5:** Chapter 9, **Unit 6:** Chapter 6 & 10.

Reference Books:

1. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *Basic Abstract Algebra*, Cambridge University Press.
2. I. S. Luthar and Inder Bir S. Passi, *Algebra: Groups*, Narosa Publishing House.
3. I.N. Herstein, *Topics in Algebra*, Wiley.
4. J. B. Fraleigh, A. *First Course in Abstract Algebra*, Narosa Publishing House.
5. M. Artin, *Algebra*, Prentice Hall of India, New Delhi.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	3	2	3	2
PO03	1	1	1	1	1	2	1
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	3	3	3
PO07	2	3	3	2	3	3	3
PO08	2	3	3	2	3	3	3
PO09	1	2	2	2	1	2	2
PO10	1	1	1	1	1	1	1
PO11	1	1	1	1	1	1	1
PO12	3	3	3	3	3	3	3
PO13	1	1	1	1	1	1	1

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs (CO1–CO7) strongly contribute to PO1. The course develops foundational and advanced knowledge of groups, subgroups, cyclic groups, permutations, normal subgroups, homomorphisms, isomorphism's, and Cayley's Theorem. Students gain conceptual clarity and structural understanding of algebraic systems. Hence, strong (3).

PO2: Practical, Professional, and Procedural Knowledge

CO1–CO4 and CO6 strongly contribute through procedural verification (group axioms, subgroup tests, element order computation, permutation operations and homomorphism properties). CO5 and CO7 moderately contribute as they involve more theoretical reasoning than procedural computation. Hence, moderate to strong (2–3).

PO3: Entrepreneurial Mind-set and Knowledge

The course is theoretical; direct entrepreneurial linkage is limited. However, CO6 (isomorphism's and structural mapping) develops structural thinking useful in cryptography and coding theory. Hence, mostly weak (1) with slight relevance in CO6 (2).

PO4: Specialized Skills and Competencies

All COs strongly develop specialized algebraic reasoning skills, including abstraction, symbolic manipulation, theorem proving, and structural analysis. This course builds mathematical maturity in abstract algebra. Hence, strong (3).

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

CO1–CO2: Structural verification. CO3–CO5: Theorem application and subgroup analysis. CO6–CO7: Structural mapping and isomorphic representation. Thus, analytical reasoning is central. Hence, strong (3).

PO6: Communication Skills and Collaboration

Students must clearly express proofs regarding normality, homomorphism's and isomorphisms (CO5–CO7 particularly). Mathematical argument presentation enhances structured communication. Hence, moderate to strong (2–3).

PO7: Research-Related Skills

CO2, CO3, CO5, CO6, and CO7 strongly support research aptitude by encouraging structural analysis, theorem application, and abstraction. Cayley's Theorem and isomorphism concepts are foundational for higher algebra research. Hence, strong (3) overall.

PO8: Learning How to Learn Skills

Abstract algebra requires independent theorem understanding and proof construction. CO2–CO7 particularly demands self-driven exploration of group structure. Thus, contribution is moderate to strong (2–3).

PO9: Digital and Technological Skills

Group theory underpins cryptography, coding theory, symmetry analysis, and computer science structures. CO2–CO7 moderately contributes by building structural and algorithmic thinking. Hence, moderate (2) overall.

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course promotes universal logical reasoning but does not directly address multicultural themes. Hence, weak (1).

PO11: Value Inculcation and Environmental Awareness

The subject encourages intellectual honesty, logical rigor, and disciplined proof writing but lacks direct environmental linkage. Hence, weak (1).

PO12: Autonomy, Responsibility, and Accountability

All COs require independent verification of properties, theorem application, and proof construction. Students develop accountability in logical justification. Hence, strong (3).

PO13: Community Engagement and Service

Direct societal linkage is limited; however, abstract algebra applications indirectly support technological development. Contribution remains weak (1).

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2024 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Mandatory (Theory)
Course Name	: Ordinary Differential Equations
Course Code	: MAT-304-MRM
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To classify differential equations by order, degree, and linearity.
2. To solve first-order differential equations using various analytical methods.
3. To understand the theory of linear equations, including superposition and the Wronskian.
4. To solve higher-order linear equations with constant coefficients.
5. To apply differential equations to geometric and physical problems (orthogonal trajectories, cooling, mixing).
6. To solve systems of linear first-order equations.
7. To apply operator and elimination methods to linear systems.

Course Outcomes:

CO1: Students will be able to classify and identify appropriate solution methods for differential equations.

CO2: Students will be able to solve first-order ODEs, including separable, exact, linear, and Bernoulli equations.

CO3: Students will be able to determine the linear independence of solutions using the Wronskian.

CO4: Students will be able to solve higher-order linear ODEs using undetermined coefficients and variation of parameters.

CO5: Students will be able to model and solve real-world problems involving orthogonal trajectories, cooling, and mixing.

CO6: Students will be able to solve systems of first-order linear equations.

CO7: Students will be able to apply the operator method to find solutions to linear systems.

Topics and Learning Points

	Teaching Hours
Unit 1: First-Order Ordinary Differential Equations	09
1.1 Basic Definitions and Concepts (Order, Degree, Linear, Non-linear)	
1.2 Separable Equations	
1.3 Exact Differential Equations. Criteria for exactness, Integrating factors	
1.4 Linear First-Order Equations and Bernoulli's Equation	
1.5 Simple Substitutions to reduce to separable/linear forms	
Unit 2: Linear Differential Equations of Higher Order	09
2.1 Basic Theory of Linear Equations: Principle of Superposition, Wronskian and Linear Independence	
2.2 Homogeneous Linear Equations with Constant Coefficients	
2.3 The Method of Undetermined Coefficients	
2.4 The Method of Variation of Parameters	
2.5 Cauchy-Euler Equations	
Unit 3: Applications of Differential Equations	06
3.1 Applications to Orthogonal Trajectories	
3.2 Applications to Newton's Law of Cooling and Mixing Problems	
Unit 4: Systems of Differential Equations	06
4.1 Introduction to Systems of First-Order Linear Equations	
4.2 Solving Linear Systems with Operator Method or Elimination Method	

Text Book:

George F. Simmons, *Differential Equations with Applications and Historical Notes*, McGraw Hill Education, 2nd Edition.

Unit 1: Chapters 1 & 2,

Unit 2: Chapter 3,

Unit 3: Chapter 2,

Unit 4: Chapter 7.

Reference Books:

1. Viorel Barbu, *Differential Equations*, Springer, 2016.
2. Dennis G. Zill, Warren S. Wright and Carol D. Wright, *Differential Equations with Boundary-Value Problems*, Brooks/Cole, 2004.
3. R. Kent Nagle, E. B. Saff and Arthur David Snider, *Fundamentals of Differential Equations*, Pearson, 2018.
4. H. S. Bear, *Differential Equations: A Concise Course*, Dover Publications, 1999.
5. Shepley L. Ross, *Differential Equations*, Wiley, 1974.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	2	3	3	3	3
PO03	1	1	1	1	3	2	2
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	3	2	2
PO07	2	3	3	3	3	3	3
PO08	2	3	3	3	3	3	3
PO09	2	2	2	2	3	3	3
PO10	1	1	1	1	1	1	1
PO11	1	1	1	2	3	1	1
PO12	3	3	3	3	3	3	3
PO13	1	1	1	1	3	2	2

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs (CO1–CO7) strongly contribute to PO1. The course builds strong theoretical understanding of first-order and higher-order ODEs, linear independence, modelling, systems of equations, and operator methods. Students develop deep conceptual clarity in differential equations. Hence, strong (3).

PO2: Practical, Professional, and Procedural Knowledge

CO1, CO2, CO4, CO5, CO6, and CO7 strongly contribute through systematic solution procedures and modeling techniques. CO3 moderately contributes as it focuses on theoretical verification using the Wronskian. Overall contribution is moderate to strong (2–3).

PO3: Entrepreneurial Mind-set and Knowledge

CO5 strongly contributes as it involves real-world modeling (cooling, mixing, orthogonal trajectories), which are directly applicable in engineering, economics, and applied sciences. CO6 and CO7 moderately support structural and system-based thinking. Other COs have limited direct relevance. Hence, weak to strong depending on CO (1–3).

PO4: Specialized Skills and Competencies

All COs strongly develop mathematical modeling skills, analytical techniques, and structured solution methods for differential equations. The ability to solve systems and apply operator methods enhances advanced competency. Hence, strong (3).

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

Every CO requires logical reasoning, classification of equations, and application of suitable solution methods. CO5 especially strengthens applied analytical skills. Therefore, contribution is strong (3) across all COs.

PO6: Communication Skills and Collaboration

Students must clearly express solution steps, justify methods, and interpret modeling results. CO5 particularly enhances explanatory ability in real-world contexts. Thus, contribution is moderate to strong (2–3).

PO7: Research-Related Skills

CO2–CO7 strongly support research skills by developing analytical techniques, theorem application, and system analysis. Understanding linear independence and operator methods is foundational for advanced mathematical research. Hence, strong (3) overall.

PO8: Learning How to Learn Skills

The course encourages independent method selection, interpretation of equations, and conceptual understanding of solution techniques. CO2–CO7 particularly foster independent problem-solving ability. Hence, moderate to strong (2–3).

PO9: Digital and Technological Skills

Differential equations form the backbone of computational modeling, simulation, and engineering software. CO5–CO7 strongly support computational and technological applications. Hence, overall contribution is moderate to strong (2–3).

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course develops universal analytical reasoning but has minimal direct cultural linkage. Hence, weak (1).

PO11: Value Inculcation and Environmental Awareness

CO5 strongly contributes by modeling natural phenomena such as cooling processes and environmental mixing problems. Other COs contribute indirectly through disciplined reasoning. Hence, weak to strong (1–3).

PO12: Autonomy, Responsibility, and Accountability

All COs require independent selection of solution techniques and logical justification of results. Students develop accountability in mathematical reasoning and modeling. Hence, strong (3).

PO13: Community Engagement and Service

CO5 moderately to strongly contributes by applying differential equations to real-life community and environmental problems. Other COs have limited direct societal linkage. Hence, weak to moderate (1–3).

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2024 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Mandatory (Practical)
Course Name	: Practical on based on Metric Spaces and Real Analysis
Course Code	: MAT-305-MRM
No. of Teaching Hours	: 60
No. of Credits	: 2

Course Objectives:

1. To develop an intuitive and visual understanding of fundamental topological concepts like open/closed sets, compactness, and connectedness through hands-on exploration in specific metric spaces.
2. To reinforce the abstract notions of sequence convergence and function continuity by implementing and testing them computationally or graphically in a practical setting.
3. To apply the powerful Banach Fixed Point Theorem to find approximate solutions to equations by verifying the contraction mapping principle.
4. To cultivate the ability to rigorously test infinite series for convergence, divergence, absolute convergence, and conditional convergence using a variety of standard tests.
5. To investigate the concept of integrability by exploring the Riemann integral for various functions, including those with discontinuities, and to understand the difference between proper and improper integrals.
6. To bridge the gap between theoretical definitions (e.g., Cauchy sequences, Lipschitz continuity) and their practical verification and implications.
7. To synthesize concepts from both metric spaces and real analysis, demonstrating their interconnections in a practical, problem-solving context.

Course Outcomes:

CO1: Students will be able to visualize and construct examples of open, closed, bounded, and compact sets in different metric spaces.

CO2: Students will implement the definitions to test the convergence of sequences in various metric spaces and analyze series for convergence using appropriate tests (e.g., Ratio, Integral, Comparison).

CO3: Students will apply the Banach Contraction Principle to find approximate fixed points of functions and distinguish between absolute and conditional convergence for series and improper integrals.

CO4: Students will verify whether a given function is continuous, uniformly continuous, or Lipschitz continuous on a given set and investigate the Riemann integrability of bounded functions with finite discontinuities.

CO5: Students will determine whether a subset of a metric space is compact by exploring open covers or sequentially, and test improper integrals for convergence.

CO6: Students will demonstrate understanding of connectedness by constructing examples of connected, disconnected, and path-connected sets.

CO7: Students will utilize computational tools and logical reasoning to validate theoretical results like the Monotone Convergence Theorem and the Cauchy Criterion for sequences.

Topics and Learning Points

	Teaching Hours
Practical based on Metric Spaces:	30
1) Visualizing Open and Closed Sets	
2) Convergence of Sequences in Metric Spaces	
3) Finding Fixed Points using Contraction Maps	
4) Exploring Continuous and Lipschitz Functions	
5) Testing Sets for Compactness	
6) Investigating Connected and Path-Connected Sets	
Practical based on Real Analysis:	30
1) Exploring Convergence and Divergence of Sequences	
2) The Monotone Convergence Theorem and the Cauchy Criterion	
3) Testing for Convergence of Series	
4) Absolute and Conditional Convergence	
5) Investigating the Riemann Integrability of Functions	
6) Convergence of Improper Integrals	

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	2	3	3	3	3	2	3
PO03	1	1	2	1	1	1	1
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	3	2	2	3
PO07	2	3	3	3	3	2	3
PO08	2	3	3	3	3	2	3
PO09	2	2	2	2	2	1	3
PO10	1	1	1	1	1	1	1
PO11	1	1	1	2	2	1	1
PO12	3	3	3	3	3	3	3
PO13	1	1	1	1	1	1	2

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs strongly support PO1 as the course integrates core concepts of metric spaces, convergence, compactness, continuity, connectedness, fixed-point theory, and integrability. Students gain a holistic and rigorous understanding of advanced analysis. Hence, strong (3).

PO2: Practical, Professional, and Procedural Knowledge

CO2–CO5 and CO7 strongly contribute through systematic application of convergence tests, fixed-point methods, compactness criteria, and integrability checks. CO1 and CO6 moderately contribute through conceptual identification and construction of examples. Hence, moderate to strong (2–3).

PO3: Entrepreneurial Mindset and Knowledge

The subject is primarily theoretical. However, CO3 (Banach Contraction Principle and convergence analysis) provides foundational tools useful in optimization and applied modeling. Therefore, contribution is mostly weak (1) with moderate (2) relevance in CO3.

PO4: Specialized Skills and Competencies

All COs strongly develop advanced mathematical skills such as abstract reasoning, theorem verification, proof construction, and analytical thinking in real analysis and topology. Hence, strong (3).

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

CO2–CO5: Analytical testing and theorem application. CO1 & CO6: Conceptual construction and visualization. CO7: Theorem validation through logical reasoning. Thus, contribution is strong (3).

PO6: Communication Skills and Collaboration

Students must clearly justify convergence tests, explain continuity and integrability conditions, and articulate logical proofs. CO4 and CO7 particularly enhance structured mathematical communication. Hence, moderate to strong (2–3).

PO7: Research-Related Skills

CO2–CO5 and CO7 strongly build research skills through rigorous proof techniques, abstract reasoning, and theorem validation. CO1 and CO6 provide foundational conceptual understanding. Hence, overall contribution is strong (3).

PO8: Learning How to Learn Skills

The course encourages independent exploration of abstract definitions and theorem applications. CO2–CO5 and CO7 particularly foster self-directed learning and conceptual integration. Hence, moderate to strong (2–3).

PO9: Digital and Technological Skills

CO7 strongly supports digital competency by integrating computational tools to validate theoretical results. Other COs moderately contribute by building theoretical foundations for computational mathematics. Hence, moderate to strong (2–3).

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course develops universal logical reasoning but has minimal direct cultural engagement. Hence, weak (1).

PO11: Value Inculcation and Environmental Awareness

CO4 and CO5 moderately contribute by exploring integrability and convergence, concepts applicable in modeling physical and environmental systems. Other COs contribute indirectly through disciplined academic practice. Hence, weak to moderate (1–2).

PO12: Autonomy, Responsibility, and Accountability

All COs require independent reasoning, logical justification, and proof verification. Students take responsibility for accurate theorem application and rigorous argumentation. Hence, strong (3).

PO13: Community Engagement and Service

The subject has limited direct societal engagement. However, CO7 moderately contributes by linking theoretical validation with computational application useful in broader academic contexts. Hence, weak to moderate (1–2).

CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics (2024 Pattern)

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Mandatory (Practical)
Course Name	: Practical based on Group Theory and Differential Equations
Course Code	: MAT-306-MRM
No. of Teaching Hours	: 60
No. of Credits	: 2

Course Objectives:

1. To provide a hands-on understanding of fundamental algebraic structures by exploring group axioms, properties, and key examples through concrete computation and verification.
2. To master the practical application of core group-theoretic concepts, including subgroups, cosets, Lagrange's Theorem, and normal subgroups, by constructing and analyzing examples.
3. To develop proficiency in analyzing and working with cyclic and permutation groups, including finding generators and decomposing permutations into disjoint cycles.
4. To develop proficiency in using computational tools or manual techniques to solve first-order differential equations and visualize their solution families.
5. To verify the analytical solutions of higher-order linear differential equations by implementing methods such as undetermined coefficients and variation of parameters.
6. To model physical phenomena (cooling, mixing, geometric trajectories) using differential equations and simulate their behavior through practical exercises.
7. To implement numerical or analytical techniques for solving systems of linear differential equations and Cauchy-Euler equations.

Course Outcomes:

CO1: Students will be able to verify whether a given set with an operation forms a group and demonstrate elementary group properties through computation.

CO2: Students will construct subgroups and cosets for given groups, and apply Lagrange's Theorem to deduce structural information about finite groups.

CO3: Students will be able to analyze cyclic groups by identifying all generators and decompose any permutation into a product of disjoint cycles, determining its order and sign.

CO4: Students will solve and plot the solutions of various first-order differential equations, demonstrating the relationship between the equation and its family of curves.

CO5: Students will verify the general and particular solutions of higher-order ODEs by applying appropriate methods and checking initial/boundary conditions.

CO6: Students will be able to interpret the results of applied problems (cooling, mixing, trajectories) in a physical or geometric context based on the solutions obtained.

CO7: Students will construct solutions for coupled systems of differential equations using the elimination method and validate the results.

Topics and Learning Points

	Teaching Hours
Practical based on Group Theory:	30
1) Exploring Group Structures and Properties	
2) Subgroups, Cosets, and Lagrange's Theorem	
3) Working with Cyclic Groups	
4) Decomposing Permutations in S_n	
5) Investigating Normal Subgroups	
6) Group Homomorphisms and Isomorphisms	
Practical based on Differential Equations:	30
1) Solving First-Order Ordinary Differential Equations	
2) Exact Differential Equations and Integrating Factors	
3) Solving Higher-Order Linear Differential Equations	
4) Applications of Differential Equations	
5) Solving Cauchy-Euler Equations	
6) Solving Systems of Linear Differential Equations	

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	3	3	3	3
PO03	1	1	2	2	2	3	2
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	3	3	3	2
PO07	2	3	3	3	3	3	3
PO08	2	3	3	3	3	3	3
PO09	1	2	2	3	2	2	3
PO10	1	1	1	1	1	1	1
PO11	1	1	1	2	2	3	1
PO12	3	3	3	3	3	3	3
PO13	1	1	1	2	2	3	2

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs strongly contribute to PO1. CO1–CO3 develop strong conceptual foundations in abstract algebra (groups, subgroups, permutations). CO4–CO7 build theoretical and applied understanding of differential equations and systems. Thus, students gain comprehensive mathematical knowledge. Hence, strong (3).

PO2: Practical, Professional, and Procedural Knowledge

Group verification, subgroup construction, permutation decomposition (CO1–CO3). Solving ODEs and systems with validation (CO4–CO7). Therefore, procedural competence is strongly developed. Hence, strong (3).

PO3: Entrepreneurial Mind-set and Knowledge

CO6 strongly contributes through modeling real-life problems (cooling, mixing, trajectories), which are relevant to applied sciences and industry. CO3–CO5 moderately support analytical and structural thinking useful in applied domains. CO1–CO2 have limited direct linkage. Hence, weak to strong (1–3).

PO4: Specialized Skills and Competencies

All COs build advanced mathematical skills:

- Abstract reasoning in algebra.
- Analytical modelling in differential equations.
- Logical validation of solutions.

Thus, specialized competencies are strongly developed. Hence, strong (3).

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

Each CO requires structured problem-solving and logical deduction:

- Structural analysis in groups (CO1–CO3)
 - Method selection and validation in ODEs (CO4–CO7)
- Analytical reasoning is central to the course. Hence, strong (3).

PO6: Communication Skills and Collaboration

Students must clearly explain algebraic proofs and interpret differential equation solutions geometrically and physically.

CO4–CO6 especially require explanation of solution behavior and interpretation. Hence, moderate to strong (2–3).

PO7: Research-Related Skills

CO2–CO7 strongly promote research aptitude through theorem application, structural reasoning, modelling, and validation of solutions. CO1 provides foundational research skills. Hence, strong (3) overall.

PO8: Learning How to Learn Skills

The course integrates abstract algebra with applied differential equations, encouraging independent method selection and conceptual understanding. CO2–CO7 particularly foster self-directed analytical learning. Hence, moderate to strong (2–3).

PO9: Digital and Technological Skills

CO4 and CO7 strongly support computational and graphical solution analysis. CO2–CO3 moderately contribute through structural and algorithmic reasoning relevant to computing. CO1 has minimal digital linkage. Hence, weak to strong (1–3).

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course develops universal analytical thinking but has minimal direct cultural linkage. Hence, weak (1).

PO11: Value Inculcation and Environmental Awareness

CO6 strongly contributes through applied modeling of physical processes (cooling, mixing). CO4–CO5 moderately support responsible interpretation of results. Algebraic components contribute indirectly through academic discipline. Hence, weak to strong (1–3).

PO12: Autonomy, Responsibility, and Accountability

All COs require independent verification, logical reasoning, and validation of solutions. Students develop accountability in mathematical argumentation and solution accuracy. Hence, strong (3).

PO13: Community Engagement and Service

CO6 moderately to strongly contribute by linking mathematical solutions to real-world physical contexts.CO4–CO5 also moderately contribute through modelling applications. Algebraic components have limited direct societal linkage. Hence, weak to moderate (1–3).

CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics (2024 Pattern)

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Elective (Theory)
Course Name	: Operations Research
Course Code	: MAT-307-MJE (A)
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To introduce the fundamental concepts of Linear Programming (LP) as a powerful tool for optimizing resources under constraints and to develop the ability to formulate real-world problems as two-variable LP models.
2. To establish a strong geometric intuition for LP solutions through the graphical method and to interpret special cases such as unboundedness, infeasibility, and alternative optima.
3. To provide a comprehensive understanding of the Simplex Method, the foundational algebraic algorithm for solving LP problems, including its mechanics and the handling of non-standard problems via the Big-M method.
4. To introduce the fundamental concept of Duality in linear programming and to explore the intricate relationships that exist between a primal problem and its dual.
5. To equip students with specialized algorithms for solving classic network models, starting with the Transportation Problem, including finding an initial solution and achieving optimality using the MODI method.
6. To master the solution techniques for the Assignment Problem as a special case of the transportation problem, using the Hungarian method for both minimization and maximization objectives.
7. To enable students to critically analyze and solve a wide range of optimization problems by selecting and applying the most appropriate LP model and solution algorithm.

Course Outcomes:

CO1: Students will be able to formulate a real-world optimization problem into a two-variable Linear Programming model and solve it using the graphical method.

CO2: Students will be able to identify and interpret special cases in LP solutions, such as unbounded, infeasible, and multiple optimal solutions, from a graphical representation.

CO3: Students will be able to apply the Simplex Method and the Big-M technique to solve standard and non-standard LP problems and recognize special cases that arise in the simplex tableau.

CO4: Students will construct the dual problem from any given primal LP formulation and relate their properties using primal-dual relationships.

CO5: Students will determine an Initial Basic Feasible Solution (IBFS) for a transportation problem and achieve an optimal solution using the Modified Distribution (MODI) method.

CO6: Students will be able to solve assignment problems for both minimization and maximization objectives by applying the Hungarian method.

CO7: Students will select and apply the correct model (LP, Transportation, Assignment) and algorithm to solve a given optimization problem efficiently.

Topics and Learning Points		Teaching Hours
Unit 1: Modeling with Linear Programming		08
1.1 Two variable LP Model		
1.2 Graphical LP solution		
1.3 Special cases in solution of graphical method		
1.4 Selected LP Applications		
Unit 2: The Simplex Method		08
2.1 LP Model in equation form		
2.2 The simplex method		
2.3 Big-M method		
2.4 Special cases in solution of simplex method		
Unit 3: Duality		02
3.1 Definition of the dual problem		
3.2 Primal dual relationship		
Unit 4: Transportation Model		08
4.1 Definition of the Transportation model		
4.2 Different methods to find initial basic feasible solution (IBFS)		
4.3 The Modified Distribution method (MODI)		
4.4 Special cases in solution of transportation problem		
4.5 Maximization case in transportation problem		
Unit 5: Assignment Model		04
5.1 Definition of the Transportation model		
5.2 The Hungarian method		
5.3 Maximization case in assignment problem		

Text Book:

J. K. Sharma, *Operations Research: Theory and Applications*, 2nd Edition, Macmillan India Ltd., 2006.

Unit 1: Chapters 2 & 3

Unit 2: Chapter 4

Unit 3: Chapter 5

Unit 4: Chapter 9

Unit 5: Chapter 10

Reference Books:

1. Hamdy A. Taha, *Operation Research*, Prentice Hall of India Pvt. Ltd, New Delhi, 2009.
2. Frederick S. Hillier and Gerald J. Lieberman, *Introduction to Operation Research*, Tata McGraw Hill.
3. P. K. Gupta and D. S. Hira, *Operation Research*, S. Chand.
4. G. Srinivasan, *Operation Research: Principles & Applications*, PHI.
5. Frank B. Alt, Michael C. Fu and Bruce L. Golden, *Perspectives In Operations Research*, Springer.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	3	3	3	3
PO03	3	2	3	2	3	3	3
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	3	2	2	2	2	3
PO07	2	2	3	3	3	2	3
PO08	2	2	3	3	3	2	3
PO09	3	2	3	2	3	3	3
PO10	1	1	1	1	1	1	1
PO11	2	2	2	2	3	2	3
PO12	3	3	3	3	3	3	3
PO13	2	2	2	2	3	3	3

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs strongly contribute to PO1. Students gain theoretical and practical understanding of Linear Programming models, Simplex and Big-M methods, duality theory, transportation, and assignment problems. The course builds complete knowledge of optimization frameworks. Hence, strong (3).

PO2: Practical, Professional, and Procedural Knowledge

This course develops procedural and professional skills by enabling students to formulate optimization models and apply standard algorithms such as Graphical Method, Simplex, MODI, and Hungarian Method. It builds systematic problem-solving abilities used in real-life decision-making and operations research. (Strong Contribution – 3)

PO3: Entrepreneurial Mind-set and Knowledge

Optimization techniques directly support decision-making, cost minimization, and profit maximization in business and industry. CO1, CO3, CO5, CO6, and CO7 strongly support entrepreneurial applications. CO2 and CO4 moderately contribute through analytical interpretation and strategic insight. Hence, moderate to strong (2–3).

PO4: Specialized Skills and Competencies

All COs build specialized quantitative decision-making skills, modeling capability, and algorithmic efficiency. Students develop competency in operations research tools widely used in industry. Hence, strong (3).

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

The course strengthens analytical thinking by training students to model real-world problems mathematically, analyze feasible regions, interpret optimal solutions, and select appropriate optimization techniques. It enhances logical reasoning and decision-making skills. (Strong Contribution – 3)

PO6: Communication Skills and Collaboration

Students must clearly interpret feasible regions, tableau results, and optimization conclusions. CO2 and CO7 particularly enhance explanation and interpretation of results. Hence, moderate to strong (2–3).

PO7: Research-Related Skills

CO3–CO5 and CO7 strongly promote research aptitude through algorithmic analysis, dual relationships, and optimality conditions. CO1–CO2 moderately contribute by developing modelling foundations. Hence, moderate to strong (2–3).

PO8: Learning How to Learn Skills

The course requires independent selection of appropriate models and algorithms. CO3–CO5 and CO7 strongly promote analytical independence and self-directed problem-solving. Hence, moderate to strong (2–3).

PO9: Digital and Technological Skills

Optimization methods are directly implemented in software such as MATLAB, Excel Solver, Python, and operations research tools. CO1, CO3, CO5, CO6, and CO7 strongly contribute to computational proficiency. Hence, strong (3) overall.

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course is quantitative and technical, with minimal direct cultural linkage. Hence, weak (1).

PO11: Value Inculcation and Environmental Awareness

Optimization techniques can support efficient resource allocation and sustainable planning. CO5 and CO7 particularly contribute by optimizing transportation and assignment of resources. Hence, moderate (2–3).

PO12: Autonomy, Responsibility, and Accountability

All COs require independent modelling decisions, algorithm selection, and validation of optimal solutions. Students take responsibility for logical consistency and optimal interpretation. Hence, strong (3).

PO13: Community Engagement and Service

Optimization models are widely used in logistics, public transportation, healthcare allocation, and community resource planning. CO5–CO7 strongly contributes to societal applications. Hence, moderate to strong (2–3).

CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics (2024 Pattern)

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Elective (Theory)
Course Name	: Graph Theory
Course Code	: MAT-307-MJE (B)
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To introduce the fundamental concepts of graph theory as a mathematical language for modeling pairwise relationships, using definitions and historical puzzles to motivate the subject.
2. To explore the concepts of connectivity in graphs and to distinguish between and characterize Eulerian graphs (edge-traversal) and Hamiltonian graphs (vertex-visitation).
3. To analyze the structure, properties, and applications of trees as fundamental, cycle-free graphs, and to understand the principles behind counting spanning trees.
4. To develop algorithmic thinking by studying simple, efficient algorithms related to graph traversal, Eulerian circuits, and finding minimal spanning trees.
5. To extend graph concepts to directed graphs (digraphs), analyzing their specific properties and understanding the structure of tournaments.
6. To introduce directed graphs as models for probabilistic processes, providing a foundational understanding of Markov chains and their basic behavior.
7. To demonstrate the wide applicability of graph theory by solving problems from diverse areas such as operations research, computer science, and logistics.

Course Outcomes:

CO1: Students will be able to model simple real-world problems and puzzles using the language of graphs, including vertices, edges, and degrees.

CO2: Students will be able to determine whether a graph is Eulerian and/or Hamiltonian by applying necessary and sufficient conditions, and construct such trails or cycles when they exist.

CO3: Students will be able to prove basic properties of trees and apply algorithms like Kruskal's or Prim's to find a minimal spanning tree in a weighted graph.

CO4: Students will be able to apply simple graph algorithms to solve problems related to connectivity, Eulerian circuits, and tree construction.

CO5: Students will be able to analyze directed graphs and apply relevant theorems to identify Eulerian directed trails and the properties of tournaments.

CO6: Students will be able to model a simple sequential or state-based process as a Markov chain using a directed graph and compute basic properties like next-state probabilities.

CO7: Students will be able to identify and explain the use of graph-theoretic models (such as paths, trees, and networks) in various applied contexts.

Topics and Learning Points		Teaching Hours
Unit 1: Introduction		08
1.1 What is a graph?		
1.2 Definition and examples		
1.3 Three puzzles		
Unit 2: Paths and cycles		07
2.1 Connectivity		
2.2 Eulerian graphs		
2.3 Hamiltonian graphs		
2.4 Some algorithms		
Unit 3: Trees		08
3.1 Properties of trees		
3.2 Counting trees		
3.3 More applications		
Unit 4: Digraphs		07
4.1 Definitions		
4.2 Eulerian digraphs and tournaments		
4.3 Markov chains		

Text Book:

Robin J. Wilson, *Introduction to Graph Theory*, Printice Hall, 4th Edition.

Unit 1: Sections 1 to 4, **Unit 2:** Sections 5 to 8,

Unit 3: Sections 9 to 11, **Unit 4:** Sections 22 to 24.

Reference Books:

1. John Clark and Derek Allan Holton, *A first look at Graph Theory*, Allied Publishers Ltd., 1995.
2. Narsingh Deo, *Graph Theory with Applications to Engineering & Computer Science*, Dover Publications.
3. R. Balakrishnan and K. Ranganathan, *A Textbook of Graph Theory*, Springer.
4. Geir Agnarsson and Raymond Greenlaw, *Graph Theory: Modeling, Applications and Algorithms*, Pearson.
5. Frank Harary, *Graph Theory*, Additon-Wesley, 1971.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	3	3	3	3
PO03	2	1	2	2	2	3	3
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	2	2	3
PO07	2	3	3	3	3	3	3
PO08	2	3	3	3	3	3	3
PO09	2	2	3	3	3	3	3
PO10	1	1	1	1	1	1	1
PO11	1	1	2	2	2	2	3
PO12	3	3	3	3	3	3	3
PO13	2	2	3	2	2	3	3

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs develop strong theoretical and conceptual understanding of graph theory, including modelling, graph properties, trees, algorithms, directed graphs, and Markov chains. Hence strong mapping across CO1–CO7.

PO2: Practical, Professional, and Procedural Knowledge

Each CO involves application of graph concepts and algorithms such as Eulerian/Hamiltonian conditions, Kruskal's/Prim's algorithms, and Markov chain modelling. Strong procedural skill development.

PO3: Entrepreneurial Mind-set and Knowledge

CO1, CO3–CO7 involve modeling and network optimization useful in logistics and applied systems (moderate to strong). CO2 has limited direct entrepreneurial linkage (weak).

PO4: Specialized Skills and Competencies

All COs build subject-specific expertise in graph modeling, theorem application, and algorithmic problem-solving. Strong contribution.

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

Every CO requires logical reasoning, theorem verification, algorithm execution, and structured analytical thinking. Hence strong mapping.

PO6: Communication Skills and Collaboration

CO2 and CO3 involve proof writing and explanation of properties; CO4–CO7 require interpretation of models. Moderate contribution.

PO7: Research-Related Skills

CO2–CO6 require theorem-based reasoning, algorithm design, and modelling (Markov chains), promoting research orientation. Strong mapping.

PO8: Learning How to Learn Skills

Algorithmic and modeling approaches in CO2–CO7 promote independent learning and adaptability to advanced mathematical topics.

PO9: Digital and Technological Skills

CO3–CO6 particularly support computational and algorithmic implementation. CO1, CO2, CO7 also relate to digital modeling concepts.

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

The course is primarily theoretical with minimal direct linkage to multicultural or inclusive dimensions.

PO11: Value Inculcation and Environmental Awareness

Applications of graphs in transportation, networks, and resource planning (CO3–CO7) indirectly promote efficient and sustainable decision-making.

PO12: Autonomy, Responsibility, and Accountability

All COs require independent proof construction, algorithm application, and validation of solutions. Strong contribution.

PO13: Community Engagement and Service

CO3–CO7 involve applications in traffic systems, communication networks, and real-world modeling, contributing to community-level problem-solving.

CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics (2024 Pattern)

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Elective (Practical)
Course Name	: C Programming
Course Code	: MAT-308-MJE (A)
No. of Teaching Hours	: 60
No. of Credits	: 2

Course Objectives:

1. To introduce the fundamental principles of programming, including algorithms, compilers, and the basic structure of a C program.
2. To develop proficiency in using core programming elements such as variables, data types, operators, and formatted input/output functions.
3. To cultivate logical reasoning and problem-solving skills by implementing control flow structures for decision-making (conditional statements) and repetition (loops).
4. To enable students to modularize code by creating and using functions, understanding the concepts of arguments and return values.
5. To introduce the concept of arrays as a fundamental data structure for storing and processing sequences of data.
6. To apply programming concepts to solve mathematical problems, such as calculating series, sequences, and performing basic statistical operations on data sets.
7. To synthesize all learned concepts through a comprehensive mini-project, fostering the ability to develop a complete, working program to solve a well-defined problem.

Course Outcomes:

CO1: Students will be able to explain the process of creating an executable program from source code and write a simple, syntactically correct C program.

CO2: Students will declare variables of appropriate data types and implement programs that perform basic arithmetic operations and user interaction using `printf` and `scanf`.

CO3: Students will construct programs utilizing conditional statements (`if`, `if-else`, `switch`) and loops (`for`, `while`, `do-while`) to control program flow.

CO4: Students will design and implement user-defined functions to break down problems into modular units and demonstrate parameter passing.

CO5: Students will declare, initialize, and manipulate single-dimensional arrays to store and process data.

CO6: Students will develop C programs to solve standard mathematical problems involving series (Fibonacci, factorial), sequences, and basic array operations (sum, average, search).

CO7: Students will design, code, and debug a complete C program (mini-project) that integrates multiple concepts like loops, functions, and arrays to solve a practical problem.

Topics and Learning Points

Teaching Hours

Theory:

12

1. **Introduction to Programming & C Environment:** Algorithm vs. Program, Introduction to Compilers, Structure of a C program
2. **Variables, Data Types, and Input/Output:** Variables, Basic Data Types, Constants, Formatted Input/Output (printf and scanf)
3. **Operators and Expressions:** Arithmetic Operators, Relational and Logical Operators, Understanding Expressions from a mathematical perspective.
4. **Control Flow - Decision Making:** if, if-else, nested if-else and switch-case statements.
5. **Control Flow – Loops:** for, while and do-while loops, break and continue loop controls.
6. **Functions:** Concept of a function, Defining and calling functions, Function arguments and return values.
7. **Arrays:** Introduction to Arrays, Declaring and accessing single-dimensional arrays.

List of practical:

48

1. Familiarization with the C Environment and First Program
2. Using Variables and Basic Input/Output
3. Implementing Arithmetic and Mathematical Expressions
4. Programs using if and if-else Statements
5. Programs using Nested if-else and switch-case
6. Implementing Loops with for and while
7. Nested Loops and Pattern Printing
8. Solving Series and Sequence Problems using Loops (e.g., Fibonacci, Factorial, Sum of series)
9. Creating and Using Simple Functions
10. Introduction to 1-D Arrays
11. Basic Operations on Arrays (Sum, Average, Search)
12. Mini Project / Comprehensive Problem Solving

Text Book:

Yashavant Kanetkar, *Let Us C*, BPB Publications.

Reference Books:

1. Brian W. Kernighan and Dennis M. Ritchie, *C Programming Language*, Pearson.
2. E. Balagurusamy, *Programming in ANSI C*, McGraw-Hill.
3. Madhav M Bokare and Nishigandha G. Kurale, *C Programming for Beginners*, Sankalp Publication.
4. Greg Perry and Dean Miller, *C Programming: Absolute Beginner's Guide*, Pearson.
5. B. Thiagarajan, *C for You*, MJP Publishers.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	3	3	3	3
PO03	2	1	2	2	2	2	2
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	2	2	3
PO07	2	2	2	2	2	2	3
PO08	2	2	3	3	3	3	3
PO09	3	3	3	3	3	3	3
PO10	1	1	1	1	1	1	1
PO11	1	1	1	1	1	1	2
PO12	3	3	3	3	3	3	3
PO13	2	1	2	2	2	2	3

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs (CO1 to CO7) help students understand basic and advanced concepts of C programming. Therefore, all COs have a strong (3) relation with PO1.

PO2: Practical, Professional, and Procedural Knowledge

All COs involve writing, compiling, running, and debugging programs. Since students practice programming in every outcome, all COs have a strong (3) relation with PO2.

PO3: Entrepreneurial Mind-set and Knowledge

CO7 (mini-project) allows students to develop a complete practical application, so it has a strong (3) relation. CO1, CO3, CO4, CO5, and CO6 develop problem-solving ability, so they have a moderate (2) relation. CO2 has less direct connection to entrepreneurship, so it has a weak (1) relation.

PO4: Specialized Skills and Competencies

All COs develop core programming skills such as logic building, modular programming, arrays, and functions. Therefore, all COs have a strong (3) relation with PO4.

PO5: Application, Problem-Solving, and Analytical Reasoning

CO3, CO6, and CO7 require strong logical thinking and algorithm development, so they have a strong (3) relation. CO1, CO2, CO4, and CO5 involve structured problem-solving, so they have a moderate (2) relation.

PO6: Communication Skills and Collaboration

CO7 involves explaining and presenting a complete program, so it has a strong (3) relation. CO4 involves modular programming and explaining logic, so it has a moderate (2) relation. CO1, CO2, CO3, CO5, and CO6 have a weak (1) relation.

PO7: Research-Related Skills

CO7 includes testing and debugging a full program, so it has a strong (3) relation. CO3, CO4, and CO6 involve logical checking and verification, so they have a moderate (2) relation. CO1, CO2, and CO5 have a weak (1) relation.

PO8: Learning How to Learn Skills

CO3, CO4, CO5, CO6, and CO7 require practice and independent learning, so they have a strong (3) relation. CO1 and CO2 have a moderate (2) relation.

PO9: Digital and Technological Skills

All COs involve programming and use of technology. Therefore, all COs have a strong (3) relation with PO9.

PO10: Multicultural Competence and Inclusive Spirit

The course is technical in nature, so all COs have a weak (1) relation with PO10.

PO11: Value Inculcation and Environmental Awareness

CO7 encourages responsible program design, so it has a moderate (2) relation. CO1 to CO6 have a weak (1) relation.

PO12: Autonomy, Responsibility, and Accountability

CO3, CO4, CO5, CO6, and CO7 require independent coding and debugging, so they have a strong (3) relation. CO1 and CO2 have a moderate (2) relation.

PO13: Community Engagement and Service

CO7 allows development of practical applications, so it has a strong (3) relation. CO3, CO4, and CO6 have a moderate (2) relation. CO1, CO2, and CO5 have a weak (1) relation.

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2023 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Major Elective (Practical)
Course Name	: Practical based on Combinatorics
Course Code	: MAT-308-MJE (B)
No. of Teaching Hours	: 60
No. of Credits	: 2

Course Objectives:

1. To establish a strong foundational understanding of the fundamental principles of counting, namely the Rule of Sum and the Rule of Product.
2. To develop proficiency in calculating and applying permutations and combinations to solve a wide variety of counting problems involving distinct objects.
3. To introduce advanced counting techniques for complex arrangements, including those with indistinguishable objects and circular configurations.
4. To equip students with the Principle of Inclusion-Exclusion as a powerful tool for counting with restrictions or overlaps.
5. To explore combinatorial identities and the Binomial Theorem, emphasizing both algebraic and combinatorial proofs.
6. To model and solve real-world problems using recurrence relations, introducing methods for their solution.
7. To synthesize all combinatorial techniques through comprehensive problem-solving, enhancing logical reasoning and analytical skills.

Course Outcomes:

CO1: Students will be able to apply the Addition and Multiplication Principles to solve basic counting problems.

CO2: Students will be able to calculate permutations and combinations to determine the number of ways to arrange or select objects from a set.

CO3: Students will be able to solve complex arrangement problems involving identical objects and circular arrangements.

CO4: Students will be able to use the Principle of Inclusion-Exclusion to compute the number of elements in unions of sets with given conditions.

CO5: Students will be able to prove basic combinatorial identities and apply the Binomial Theorem for expansion and coefficient calculation.

CO6: Students will be able to formulate simple recurrence relations from problem statements and solve them using appropriate methods.

CO7: Students will be able to analyze and solve multi-step counting problems by selecting and integrating appropriate combinatorial techniques.

Topics and Learning Points**Teaching Hours****Theory:****12**

1. The Basics of Counting: Addition Principle, Multiplication Principle, Factorials.
2. Permutations and Combinations
3. Combinatorial Identities and The Binomial Theorem
4. Permutations of Indistinguishable Objects & Circular Arrangements
5. The Principle of Inclusion-Exclusion (PIE)
6. Introduction to Recurrence Relations

List of practical:**48**

1. Problems on the Rule of Sum and Rule of Product
2. Applying Permutations to Problems
3. Applying Combinations to Problems
4. Mixed Problems on Permutations and Combinations
5. Proving and Using Combinatorial Identities
6. Problems based on the Binomial Theorem
7. Arrangements with Indistinguishable Objects
8. Problems on Circular Arrangements
9. Applying the Principle of Inclusion-Exclusion (Basic)
10. Advanced Problems using Inclusion-Exclusion
11. Formulating and Solving Simple Recurrence Relations
12. Comprehensive Problem-Solving and Review

Text Book:

Richard A. Brualdi, *Introductory Combinatorics*, Pearson.

Reference Books:

1. Alan Tucker, *Applied Combinatorics*, John Wiley & Sons, 2012.
2. Foo Kean Pew and Lin Mingyan Simon, *Principles and Techniques in Combinatorics*, World Scientific.
3. Fred S. Roberts and Barry Tesman, *Applied Combinatorics*, CRC Press.
4. Edward A. Bender and S. Gill Williamson, *Foundations of Combinatorics with Applications*, Dover Books.
5. Mitchel T. Keller and William T. Trotter, *Applied Combinatorics*, CreateSpace Independent Publishing Platform, 2016.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	3	3	3	3	3	3
PO02	3	3	3	3	3	3	3
PO03	1	2	2	2	1	2	3
PO04	3	3	3	3	3	3	3
PO05	3	3	3	3	3	3	3
PO06	1	1	2	2	3	2	2
PO07	1	1	2	2	2	3	3
PO08	2	2	3	3	2	3	3
PO09	1	1	1	1	1	2	2
PO10	1	1	1	1	1	1	1
PO11	1	1	1	1	1	1	2
PO12	2	2	3	2	2	3	3
PO13	1	1	1	1	1	1	2

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs (CO1 to CO7) build strong conceptual understanding of counting principles, permutations, combinations, binomial theorem, inclusion-exclusion, and recurrence relations. Therefore, all COs have a strong (3) relation with PO1.

PO2: Practical, Professional, and Procedural Knowledge

All COs require students to apply systematic procedures to solve counting and arrangement problems. Since each outcome involves step-by-step mathematical methods, all COs have a strong (3) relation with PO2.

PO3: Entrepreneurial Mindset and Knowledge

CO7 involves solving multi-step real-life type counting problems, so it has a strong (3) relation. CO2, CO3, CO4, and CO6 develop structured problem-solving skills useful in decision-making, so they have a moderate (2) relation. CO1 and CO5 have a weak (1) relation as they are mainly theoretical.

PO4: Specialized Skills and Competencies

All COs develop specialized combinatorial and analytical skills such as arrangement techniques, recurrence solving, and identity proofs. Hence, all COs have a strong (3) relation with PO4.

PO5: Application, Problem-Solving, and Analytical Reasoning

CO3, CO4, CO6, and CO7 require higher-level analytical thinking and integration of multiple techniques, so they have a strong (3) relation. CO1, CO2, and CO5 involve structured reasoning, so they also strongly support analytical ability. Overall, all COs have a strong (3) relation with PO5.

PO6: Communication Skills and Collaboration

CO5 involves proving identities and explaining steps clearly, so it has a strong (3) relation. CO3, CO4, CO6, and CO7 require logical explanation of multi-step solutions, so they have a moderate (2) relation. CO1 and CO2 have a weak (1) relation.

PO7: Research-Related Skills

CO6 and CO7 involve formulation of recurrence relations and solving complex problems, so they have a strong (3) relation. CO3, CO4, and CO5 involve logical reasoning and proof techniques, so they have a moderate (2) relation. CO1 and CO2 have a weak (1) relation.

PO8: Learning How to Learn Skills

CO3 to CO7 require continuous practice and selection of suitable methods for different problems, so they have a strong (3) relation. CO1 and CO2 have a moderate (2) relation.

PO9: Digital and Technological Skills

CO6 (recurrence relations) and CO7 (complex counting problems) can be implemented using computational tools, so they have a moderate (2) relation. CO1 to CO5 have a weak (1) relation as they are mostly theoretical.

PO10: Multicultural Competence and Inclusive Spirit

The course is theoretical in nature and does not directly address multicultural aspects. Therefore, all COs have a weak (1) relation.

PO11: Value Inculcation and Environmental Awareness

CO7 promotes structured and responsible problem-solving, so it has a moderate (2) relation. CO1 to CO6 have a weak (1) relation.

PO12: Autonomy, Responsibility, and Accountability

CO3, CO6, and CO7 require independent logical reasoning and multi-step solution development, so they have a strong (3) relation. CO1, CO2, CO4, and CO5 have a moderate (2) relation.

PO13: Community Engagement and Service

CO7 supports solving applied counting problems that may relate to planning or resource allocation, so it has a moderate (2) relation. CO1 to CO6 have a weak (1) relation.

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2024 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: On the Job Training (OJT)
Course Name	: On the Job Training
Course Code	: MAT-309-OJT
No. of Teaching Hours	: 60
No. of Credits	: 2

Course Objectives:

1. To expose students to real-world work environments where mathematical concepts are applied in industries, research institutes, or academic settings.
2. To bridge the gap between theoretical mathematical knowledge and its practical implementation in sectors such as IT, banking, data science, education, or analytics.
3. To develop professional communication and documentation skills by requiring students to maintain work logs, present findings, and submit technical reports.
4. To enhance problem-solving abilities by allowing students to tackle real-time challenges using mathematical modeling, statistical analysis, or computational tools.
5. To cultivate teamwork, work ethics, and professional conduct by integrating students into existing projects and workflows within the host organization.
6. To provide hands-on experience with industry-standard software and tools (e.g., Python, R, MATLAB, SQL, or Excel) relevant to mathematical applications.
7. To prepare students for competitive exams and higher education by demonstrating the relevance of mathematics in interdisciplinary fields.

Course Outcomes:

CO1: Students will be able to apply core mathematical concepts (calculus, linear algebra, differential equations, or statistics) to solve problems encountered in the professional workplace.

CO2: Students will be able to demonstrate proficiency in using at least one computational tool or programming language for data analysis, simulation, or mathematical computation.

CO3: Students will be able to communicate technical information effectively through well-structured reports, presentations, and professional interactions with colleagues and supervisors.

CO4: Students will be able to exhibit professional behavior, including punctuality, responsibility, teamwork, and adaptability to the organizational culture.

CO5: Students will be able to evaluate real-world data or scenarios using appropriate mathematical or statistical techniques to derive meaningful conclusions.

CO6: Students will be able to integrate theoretical knowledge with practical experience to identify potential career paths or areas for higher studies in mathematics and allied fields.

CO7: Students will be able to produce a comprehensive training report that documents the work undertaken, methodologies used, and key learnings from the internship experience.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
	CO1	CO2	CO3	CO4	CO5	CO6	CO7
PO01	3	2	2	2	3	3	2
PO02	3	3	2	3	3	3	2
PO03	2	2	2	3	2	3	2
PO04	3	3	2	2	3	3	2
PO05	3	3	2	2	3	3	2
PO06	2	2	3	3	2	2	3
PO07	2	3	2	2	3	3	3
PO08	2	2	2	3	2	3	2
PO09	2	3	2	2	3	2	2
PO10	1	1	2	3	1	2	2
PO11	1	1	2	3	2	2	2
PO12	2	2	2	3	2	3	3
PO13	2	2	3	3	2	2	3

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

CO1, CO5 and CO6 show a strong relation because students apply core mathematical concepts and evaluate real-world data. CO2, CO3, CO4 and CO7 show moderate relation as they support knowledge through tools, communication, professional behaviour, and reporting.

PO2: Practical, Professional, and Procedural Knowledge

CO1, CO2, CO4 and CO5 have strong relation as students use mathematics, computational tools, and professional practices in real workplace situations. CO3, CO6 and CO7 moderately support professional development.

PO3: Entrepreneurial Mind-set and Knowledge

CO4 and CO6 show strong relation as students develop adaptability and explore career opportunities. The remaining COs show moderate relation by supporting applied thinking and professional growth.

PO4: Specialized Skills and Competencies

CO1, CO2, CO5 and CO6 strongly contribute because students develop specialized mathematical and computational skills. CO3, CO4 and CO7 moderately support competency development through reporting and workplace exposure.

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

CO1, CO2, CO5 and CO6 show strong relation since they involve analytical reasoning, data evaluation and problem-solving. CO3, CO4 and CO7 moderately support logical thinking and structured work.

PO6: Communication Skills and Collaboration

CO3 and CO7 have strong relation because students prepare structured reports and communicate technical information effectively. CO1, CO2, CO4 and CO5 show moderate support through professional collaboration.

PO7: Research-Related Skills

CO2, CO5, CO6 and CO7 strongly relate as students analyze data, apply appropriate techniques and document methodologies. CO1, CO3 and CO4 moderately contribute to research-related skills.

PO8: Learning How to Learn Skills

CO4 and CO6 strongly support this PO as students adapt to organizational culture and explore higher studies or career paths. Other COs moderately contributes through experiential learning.

PO9: Digital and Technological Skills

CO2 and CO5 show strong relation because students use computational tools and data analysis techniques. CO1, CO3, CO4, CO6 and CO7 moderately support digital skill development.

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

CO4 shows strong relation as students demonstrate professional behavior, punctuality and teamwork. CO3, CO6 and CO7 moderately support inclusive and professional interaction. CO1, CO2 and CO5 have weak relation.

PO11: Value Inculcation and Environmental Awareness

CO4 shows strong relation due to responsibility and ethical behavior in workplace settings. CO3, CO5, CO6 and CO7 moderately contribute to value-based professional conduct. CO1 and CO2 show weak relation.

PO12: Autonomy, Responsibility, and Accountability

CO4, CO6 and CO7 strongly relate because students demonstrate responsibility, independent work and accountability during internship and report preparation. Other COs moderately support this outcome.

PO13: Community Engagement and Service

CO3, CO4 and CO7 show strong relation as students communicate learning outcomes and work collaboratively in professional settings. Remaining COs moderately contribute to community and professional engagement.

**CBCS Syllabus as per NEP 2020 for T.Y.B.Sc. Mathematics
(2024 Pattern)**

Name of the Programme	: B.Sc. Mathematics
Program Code	: USMT
Class	: T.Y.B.Sc.
Semester	: V
Course Type	: Minor (Theory)
Course Name	: Basics of Abstract Algebra and Modern Analysis
Course Code	: MAT-310-MN
No. of Teaching Hours	: 30
No. of Credits	: 2

Course Objectives:

1. To introduce the fundamental algebraic structures of groups and rings, emphasizing their defining axioms and basic properties.
2. To develop an understanding of key algebraic concepts such as subgroups, cyclic groups, integral domains, and fields, and to explore the relationships between these structures.
3. To generalize the concepts of distance and convergence from real numbers to the abstract setting of metric spaces.
4. To analyze the topological properties of metric spaces, focusing on the central ideas of open and closed sets, compactness, and connectedness.
5. To investigate the crucial properties of completeness and connectedness and their preservation under continuous functions.
6. To explore the profound relationship between the structure of a space (compact, connected) and the behavior of continuous functions defined on it.
7. To build a solid foundation in abstract mathematical reasoning, preparing students for advanced studies in pure and applied mathematics.

Course Outcomes:

CO1: Students will be able to verify whether a given set with a binary operation forms a group or a ring and demonstrate elementary properties such as the uniqueness of identities and inverses.

CO2: Students will be able to identify subgroups and cyclic subgroups of a group, and distinguish between rings, integral domains, and fields with examples.

CO3: Students will be able to determine whether a given function defines a metric and identify open, closed, and compact sets in specific metric spaces.

CO4: Students will be able to test sequences for the Cauchy property to determine the completeness of a metric space and analyze sets for connectedness.

CO5: Students will be able to apply the definitions to prove whether a function between metric spaces is continuous.

CO6: Students will be able to explain fundamental consequences of compactness and connectedness, such as the attainment of bounds on compact sets and the preservation of intervals by continuous functions on connected sets.

CO7: Students will be able to synthesize concepts from algebra and analysis to compare the structural properties of different mathematical objects like groups, rings, and metric spaces.

Topics and Learning Points

	Teaching Hours
Unit 1: Groups	08
1.1 Introduction to Groups	
1.2 Basic Properties of Groups	
1.3 Subgroups	
1.4 Cyclic Groups	
Unit 2: Rings	07
2.1 Introduction to Rings	
2.2 Subrings	
2.3 Integral Domains	
2.4 Fields	
Unit 3: Metric Spaces and Compactness	08
3.1 Basics of Metric Spaces	
3.2 Open and Closed Sets	
3.3 Compactness	
3.4 Continuous Functions on Metric Spaces	
Unit 4: Completeness and Connectedness	07
4.1 Cauchy Sequences and Completeness	
4.2 Connectedness	
4.3 Properties of Continuous Functions	

Text Book:

1. Joseph Gallian, *Contemporary Abstract Algebra*, Narosa Publishing House.
Unit 1: Chapters 2, 3 & 4.
Unit 2: Chapters 12 & 13.
2. Richard R. Goldberg, *Methods of Real Analysis*, Oxford & IBH Publishing Co. Pvt. Ltd., Indian Edition.
Unit 3: Chapters 6 & 7.
Unit 4: Chapters 6 & 7.

Reference Books:

1. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *Basic Abstract Algebra*, Cambridge University Press.
2. I. S. Luthar and Inder Bir S. Passi, *Algebra: Groups*, Narosa Publishing House.
3. J. B. Fraleigh, A. *First Course in Abstract Algebra*, Narosa Publishing House.
4. D. Somasundaram and B. Choudhary, *A first course in Mathematical Analysis*, Narosa Publishing House, 1997.
5. Robert G. Bartle and Donald Sherbert, *Introduction to Real Analysis*, John Wiley and Sons, 3rd Edition.

CO-PO Mapping

Weightage: 1 – weak or low relation, 2 – moderate or partial relation, 3 – strong or direct relation

Programme Outcomes	Course Outcomes						
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PO05	3	3	3	3	3	3	3
PO06	2	2	2	2	2	2	2
PO07	3	3	3	3	3	3	3
PO08	2	2	2	2	2	2	3
PO09	2	2	2	2	2	2	2
PO10	1	1	1	1	1	1	1
PO11	1	1	1	1	1	1	1
PO12	2	2	2	2	2	2	2
PO13	1	1	1	1	1	1	2

Justification for the mapping

PO1: Comprehensive Knowledge and Understanding

All COs show strong relation because students learn and verify fundamental algebraic and analytical structures such as groups, rings, metric spaces, compactness, connectedness, and continuity. The course builds strong theoretical foundations.

PO2: Practical, Professional, and Procedural Knowledge

CO1, CO2, CO5, and CO6 show strong relation as students apply definitions and prove properties logically. CO3, CO4, and CO7 show moderate relation through analytical reasoning and structural comparisons.

PO3: Entrepreneurial Mind-set and Knowledge

Most COs show moderate relation as abstract reasoning and logical thinking help in decision-making and structured analysis. CO7 shows strong relation because it develops the ability to compare and synthesize mathematical structures.

PO4: Specialized Skills and Competencies

All COs strongly support this PO because the course develops specialized knowledge in abstract algebra and metric space theory.

PO5: Capacity for Application, Problem-Solving, and Analytical Reasoning

All COs strongly relate since students verify structures, test properties, prove theorems, and analyze mathematical objects using rigorous reasoning.

PO6: Communication Skills and Collaboration

All COs show moderate relation because students must explain proofs and justify results clearly in written and oral form.

PO7: Research-Related Skills

All COs strongly relate as students apply definitions, construct proofs, analyze properties, and synthesize concepts — all of which are essential research skills in mathematics.

PO8: Learning How to Learn Skills

All COs moderately contribute because abstract algebra and analysis require independent thinking and conceptual understanding. CO7 strongly supports lifelong learning through synthesis of ideas.

PO9: Digital and Technological Skills

All COs show moderate relation as logical reasoning and structural analysis support computational thinking, though the course is mainly theoretical.

PO10: Multicultural Competence, Inclusive Spirit, and Empathy

All COs show weak relation because the course focuses mainly on theoretical mathematical concepts.

PO11: Value Inculcation and Environmental Awareness

All COs show weak relation since the subject is purely mathematical and theoretical in nature.

PO12: Autonomy, Responsibility, and Accountability

All COs moderately support this PO as students independently construct proofs and solve abstract problems.

PO13: Community Engagement and Service

CO7 shows moderate relation as synthesis of mathematical structures may support advanced applications. Other COs show weak relation since the course is theory-oriented.