(Bachelor of Science) (Mathematics)
(B.Sc.) (Mathematics) Semester (V)

Course Code	US05CMTH51	Title of the Course	Real Analysis-I
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. To introduce fundamental properties of field of real numbers 2. To provide set related fundamentals concepts of real analysis. 3. To provide fundamentals of sequence and series.

Course Content		
Unit	Description	Weightage* (%)
1.	Algebraic structure and Field Structure, Order Structure and Ordered Field, Bounded Sets, Supremum and Infimum of a set, Completeness and Order Completeness in $\mathbb{R}$, Archimedean Property, Axioms of a Complete Ordered Field, Absolute Value and its properties.	25%
2.	Neighbourhood of a Point, Properties of neighbourhood, Interior Point and Interior of a Set, Limit Point of a Set, Bolzano-Weierstrass Theorem, Closed Sets, Closure of a Set.	25%
3.	Sequence and it's range, Bounded Sequences, Convergence of a Sequence, Limit Point of a Sequence, Bolzano-Weierstrass Theorem for sequences, Limit Superior and Limit Inferior of a Sequence, Non-convergent sequence, Cauchy's General Principle of Convergence, Cauchy Sequences, Algebra of Sequences, Monotonic Sequences.	25%
4.	Infinite Series, A Necessary Condition for the Convergence, Cauchy's General Principle of Convergence, Some Preliminary Theorems, Positive Term Series, Comparison Tests for Positive Term Series, Cauchy' Root Test, D'Alembert Ratio Test, Integral Test, Alternating Series, Absolute Convergence.	25%

Teaching-Learning Methodology	Classroom teaching, Presentation by students, Use of ICT whenever required.

Evaluation Pattern		
Sr. No.	Details of the Evaluation	Weightage
1.	Internal Written / Practical Examination (As per CBCS R.6.8.3)	15%
2.	Internal Continuous Assessment in the form of Practical, Viva-voce, Quizzes, Seminars, Assignments, Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: Upon completion of the course, the student will be able to….	
1.	understand fundamental properties of the field of real numbers
2.	understand set theoretic basics of real analysis
3.	understand basics of sequence and series.
4.	acquired skills to apply understanding of concepts understood at (1), (2), (3) and (4) in solving relevant problems.

Suggested References:	
Sr. No.	References
1.	S. C. Malik, Principles of Real Analysis, Fifth Edition, New Age International, New Delhi, 2021.
2	S. C. Malik and Savita Arora, Mathematical Analysis, Fifth Edition, New Age International Pvt. Ltd., New Delhi, 2019.
3	Walter Rudin, Principles of Mathematical Analysis, Third Edition, McGraw-Hill, Inc, New Delhi, 2017
4	R. G. Bartle, D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Pvt. Ltd., New Delhi, 2011.
5	Gerald G. Bilodeau, Paul R. Thie, G. E. Keough, An Introduction to Analysis, 2nd Ed. Jones and Barlett India Pvt. Ltd, 2009.

On-line resources to be used if available as reference material

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(Bachelor of Science) (Mathematics)
(B.Sc.) (Mathematics) Semester (V)

Course Code	US05CMTH52	Title of the Course	Real Analysis-II
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. To introduce fundamentals of Limit, Continuity, and Differentiability of functions of one variable. 2. To understand important theorems and series expansion of functions. 3. To introduce the function of several variables to find limit, continuity, and differentiability. 4. To find extreme values of functions of two variables.

Course Content		
Unit	Description	Weightage* (%)
1.	Limit and Continuity for Functions of one variable, Uniqueness of limit, Algebra of limits, Continuous Functions on Closed and Bounded Intervals, Uniform Continuity, Derivability of a Function, and Properties of Derivable Functions.	25%
2.	Increasing and Decreasing Functions, Darboux Theorem, Rolle's Theorem, Lagrange's and Cauchy's Mean Value Theorems, Taylor's Theorem with Lagrange's Form of Remainder, and Cauchy's Form of Remainder, Maclaurin's Theorem, Generalized Mean Value Theorem, Taylor's and Maclaurin's Series Expansions of Exponential and Trigonometric Functions, $ln(1 + x)$ and $(1 + x)^n$.	25%
3.	Functions of Several Variables: Explicit and Implicit Functions, Neighbourhood of a Point, Limit and Continuity, Partial Derivatives, Differentiability, Partial Derivatives of higher order, Differentials of Higher Order, Functions of Function.	25%
4.	Change of variables, Taylor's Theorem, and Maclaurin's Theorem for Function of two variables, Extreme Values of Functions of two variables.	25%

Teaching-Learning Methodology	Classroom teaching, Presentation by students, and Use of ICT whenever required.

Evaluation Pattern		
Sr. No.	Details of the Evaluation	Weightage
1.	Internal Written / Practical Examination (As per CBCS R.6.8.3)	15%

2.	Internal Continuous Assessment in the form of Practical, Viva-voce, Quizzes, Seminars, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: Upon completion of the course, the students will be able to…	
1.	understand fundamentals of Limit, Continuity, and Differentiability of real-valued functions of real variables.
2.	understand important theorems: Mean Value Theorems and Taylor's theorem for series expansion of functions and their applications.
3.	understand the limit, continuity, and partial differentiability of functions of two variables and their respective properties.
4.	acquired skills to apply understanding of concepts understood at (1), (2), (3) and (4) in solving relevant problems.

Suggested References:	
Sr. No.	References
1.	S. C. Malik, Principles of Real Analysis, Fifth Edition, New Age International, New Delhi, 2021.
2	S. C. Malik and Savita Arora, Mathematical Analysis, Fifth Edition, New Age International Pvt. Ltd., New Delhi, 2019.
3	R. G. Bartle, D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Pvt. Ltd., New Delhi, 2011.
4	S. R. Ghorpade and B. V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.
5	Dipak Chatterjee, Real Analysis, Second Edition Prentice-Hall India Pvt. Ltd., New Delhi, 2012.

On-line resources to be used if available as reference material
On-line Resources

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(Bachelor of Science) (Mathematics)
(B.Sc.) (Mathematics) Semester (V)

Course Code	US05CMTH53	Title of the Course	Group Theory
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. To introduce the importance of the basic properties of Groups. 2. To teach how to generate the group by given specific conditions. 3. To teach Subgroups, Normal subgroups, and relevant theorems. 4. To extend group structure to finite permutation groups.

Course Content		
Unit	Description	Weightage* (%)
1.	Binary operations, Semi group, Group, Finite group, Infinite group, Cancellation laws, Subgroups, Operations on subgroups (union & intersection), Centre of the group, Abelian groups, Order of elements, Cyclic group, Generators of cyclic groups, Laws of exponents, Subgroups, Centre of the group, Cyclic group.	25%
2.	Cosets of subgroup, Lagrange's theorem, Index of subgroup, Normal subgroup, Euler's theorem, Fermat's theorem, Isomorphism, Isomorphic groups, Automorphism, Inner Automorphism.	25%
3.	Homomorphism, Kernel of Homomorphism, Simple group, Commutator subgroup, Quotient groups, First, Second, and Third Isomorphism theorem, Homomorphic groups, Isomorphic groups, Automorphism, Inner Automorphism.	25%
4.	Direct Product of groups, External Direct Product of groups, Permutation groups, Transposition, Cycle, Signature of Permutation, Even and Odd Permutation, Cayley's theorem for the group.	25%

Teaching-Learning Methodology	Classroom teaching, Presentation by students, and Use of ICT whenever required.

Evaluation Pattern		
Sr. No.	Details of the Evaluation	Weightage*
1.	Internal Written / Practical Examination (As per CBCS R.6.8.3)	15%

2.	Internal Continuous Assessment in the form of Practical, Viva-voce, Quizzes, Seminars, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: After successful completion of the course, students will be able to:	
1.	understand the fundamentals of groups and subgroups.
2.	develop an understanding of cosets, Isomorphic groups, Automorphism, and Homomorphism of groups.
3.	understand Permutation groups.
4.	acquired skills to apply understanding of concepts understood at (1), (2), (3) and (4) in solving relevant problems

Suggested References:	
Sr. No.	References
1.	N. S. Gopalakrishnan, University Algebra, Second Edition, Wiley Eastern Ltd., New Delhi, 1994.
2.	I. N. Herstein, Topics in algebra, Second Edition, Wiley Eastern Limited, India, 1975.
3.	Joseph A. Gallian, Contemporary Abstract Algebra, Ninth Edition, Narosa Pub. House, New Delhi, 2017.
4.	AshaRani Singal, Algebra, R Chand & Co., New Delhi, 2010.

On-line resources to be used if available as reference material

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(Bachelor of Science) (Mathematics)
(B.Sc.) (Mathematics) Semester (V)

Course Code	US05CMTH54	Title of the Course	Metric Spaces and Topological Spaces
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. Define countable sets. Define Metric space. In the context of metric space generalize key concepts appearing in analysis like convergence and divergence of sequence and series, open and closed sets, limit and continuity of functions and homeomorphism. 2. Define topological space. In the context of topological spaces define open and closed sets, limit and continuity of functions, homeomorphism and connected spaces.

Course Content		
Unit	Description	Weightage* (%)
1.	Equivalent sets, Countable sets, Metric spaces, Cluster point, Limit of a function, Convergence of a sequence, Cauchy sequence, Uniqueness of limit of a sequence, Open ball.	25%
2.	Continuous functions on a Metric space, Open set, Limit point of a set, Closure of set, Closed set, Homeomorphism, and Dense set.	25%
3.	Topological spaces: Definition and Examples, Coarser and Finer topologies, Closed sets, Neighbourhood of a point, Door space, Cluster point.	25%
4.	Closure of set, Dense set in a topological space, Interior of a set, Continuous function, Bicontinuous function, homomorphism in a topological space, Connected spaces.	25%
Teaching-Learning Methodology	Classroom teaching, Presentation by students, and Use of ICT whenever required.	

Evaluation Pattern		
Sr. No.	Details of the Evaluation	Weightage
1.	Internal Written / Practical Examination (As per CBCS R.6.8.3)	15%

2.	Internal Continuous Assessment in the form of Practical, Viva-voce, Quizzes, Seminars, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: After successful completion of the course, students will be able to:	
1.	understand the Equivalent sets, Countability of the set, metric spaces, limit, and continuity of functions on Metric spaces.
2.	to develop a basic understanding of Topological spaces and limit and continuity functions on Topological spaces.
3.	identify the connected and disconnected Topological spaces.
4.	acquired skills to apply understanding of concepts understood at (1), (2), (3) and (4) in solving relevant problems

Suggested References:	
Sr. No.	References
1.	Richard R. Goldberg, Methods of Real Analysis, Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi, Revised Ed., 1970.
2	M. J. Mansfield, Introduction to Topology, Litton Educational Publishing Inc., U.S.A., 1963.
3	G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2017.
4	S. Kumaresan, Topology of Matric Spaces, Second Edition, Narosa Pub. House, 2018.
5	Walter Rudin, Principles of Mathematical Analysis, Third Edition, McGraw-Hill Education, New Delhi, 2017.

On-line resources to be used if available as reference material

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(Bachelor of Science) (Mathematics)
(B.Sc.) (Mathematics)Semester (V)

Course Code	US05CMTH55	Title of the Course	Mathematics Practical
Total Credits of the Course	8	Hours per Week	16 hours

Course Objectives:	1. To provide an introduction to Python and conditional statements. 2. To understand basic terminology related to Python - Data Structures. 3. To provide basic knowledge of NumPy libraries. 4. To develop problem-solving skills at UG-level Mathematics.

Course Content		
Parts	Description	Weightage* (%) (Marks)
Part-1	Getting started with Python Introduction to programming, Introduction to python, naming rules of variables, expressions, operator precedence rule, conditional statements: if statement, else statement, Elif statement, try/except statement, and its examples.	25% (50 Marks)
Part-2	Python: Data Structures Functions: using functions and building functions, loops and iterations: for loop and while loop, strings, slicing strings, manipulating strings, lists, manipulating lists, building lists, comparison of lists and strings, dictionaries, tuples.	25% (50 Marks)
Part-3	Python: NumPy libraries Introduction to python libraries, introduction and importance of NumPy library, creating an array, editing array, different array operations, matrices and their operations, eigenvalues, and eigenvectors using NumPy library.	25% (50 Marks)
Part-4	Problems & Exercises in Mathematics-I **Functions of Real Variable:** Functions of one Real Variable: Limit, continuity, intermediate value property, differentiation, Rolle's Theorem, mean value theorem, L'Hospital rule, Taylor's theorem, Taylor's series, maxima and minima, Riemann integration (definite integrals and their properties), fundamental theorem of calculus. Functions of Two or Three Real Variables: limit, continuity, partial derivatives, total derivative, maxima, and minima.	25% (50 Marks)

	Real Analysis: Sequences and Series of Real Numbers: convergence of sequences, bounded and monotone sequences, Cauchy sequences, Bolzano-Weierstrass theorem, absolute convergence, tests of convergence for series – comparison test, ratio test, root test; Power series (of one real variable), radius and interval of convergence, term-wise differentiation and integration of power series. **Groups:** cyclic groups, abelian groups, non-abelian groups, permutation groups, normal subgroups, quotient groups, Lagrange's theorem for finite groups, and group homomorphisms.	

Teaching-Learning Methodology	Classroom teaching, Practical on Computers, Use of ICT whenever required.

Evaluation Pattern		
Sr. No.	Details of the Evaluation	weightage (%)
1.	Internal Practical Examination (As per CBCS R.6.8.3)	15%
2.	Internal Continuous Assessment in the form of Practical, Viva-voce, Quizzes, Seminars, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Practical Examination	70%

Course Outcomes: Upon completion of the course, the students will be able to…	
1.	understand the basic knowledge of Python.
2.	create a basic programme using Python-Data structure.
3.	think about new fields such as Deep learning, Machine learning, Data Science, etc…using basic knowledge of the NumPy python library
4.	get benefits in different competitive examinations of Mathematics.

Suggested References:	
Sr. No.	References
1.	https://www.py4e.com/book
2.	Introduction to Computation and Programming Using Python by John V Guttag, Prentice Hal
3.	Python: The Complete Reference, by Martin C. Brown, McGraw Hill Education
4.	https://numpy.org/learn/#beginners
5.	S. C. Malik, Principles of Real Analysis, 4th Edition, New Age International, New Delhi, 2018.
6.	R. G. Bartle, D. R. Sherbert, Introduction to Real Analysis, Third Edition, Wiley India Pvt. Ltd., New Delhi, 1999.
7.	N. S. Gopalakrishnan, University Algebra, 2nd Edition, Wiley Eastern Ltd., New Delhi 1994.
8.	Joseph A. Gallian, Contemporary Abstract Algebra, 4th Edition, Narosa Pub. House, New Delhi, 2008.
On-line resources to be used as reference material	

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