SARDAR PATEL UNIVERSITY
(Under the Choice based Credit Scheme)
STRUCTURE WITH EFFECT FROM:2022-23
M.Sc. (Mathematics) Semester-3

Programme Outcome (PO) - For MSc Mathematics Programme	Master of Science program provides extended theoretical and practical knowledge of different science subjects. Master of Science programme at Sardar Patel University is designed keeping the overall back ground preparation in mind for the student to either seek a job or to become an entrepreneur. The students, after completion of Bachelor of Science can select the master's programme in the subject they have had at the final year or in a related discipline (depending upon eligibility criteria prescribed by university). **Programme outcomes: At the end of the program, the students will be able to** 1. Have a deep understanding of both the theoretical and practical concepts in the respective subject. 2. Understand laboratory processes and use scientific equipments and work independently. 3. Develop research temperament as a consequence of their theory and practical learning. 4. Communicate scientific information in oral and written form. 5. Understand the issues related to nature and environmental contexts and think rationally for sustainable development. 6. The students are able to handle unexpected situations by critically analyzing the problem.
Programme Specific Outcome (PSO) - For MSc Mathematics Semester	The Postgraduate would be able to PSO 1 understand the basic concepts of algebra, analysis, computational methods, optimization, differential equations and their importance as an abstract phenomenon and also some real-world problems. PSO 2 analyze and solve the well-defined problems. Utilize the principles of scientific enquiry, thinking analytically, clearly and critically, while solving variety of problems. PSO 3 compete the world through their ability of creative and critical thinking which is developed and built through seminars and problem-solving sessions. PSO 4 handle the advanced techniques in algebra, analysis, computational methods, optimization, differential equations to analyze and design algorithms for solving variety of problems. PSO 5 learn and prepare mathematical algorithms, select and apply appropriate methods, resources and computing tools such as Excel, MATLAB, Python, etc. PSO 6 communicate effectively about their mathematical abilities on the activities, with their peers and society at large. PSO 7 select, interpret and critically evaluate information from a range of sources that include books, scientific reports, journals, etc. PSO 8 apply the knowledge of Mathematics in all the fields of learning including higher research and extensions. Recognize the need to engage in lifelong learning through continuous education, and research leading to higher degrees like Ph. D.

To Pass	At least 40% Marks in the University Examination in each paper and 40% Marks in the aggregate of University and Internal examination in each course of Theory, Practical & 40% Marks in Viva-voce.

Course Type	Course Code	Name of the course	Employability/Skill Enhancement/Entrepreneurship	T /P	Credit	Exam Duration in hrs	Component of Marks		
							Internal	External	Total
							Total/ Passing	Total/ Passing	Total/ Passing
Core Courses	PS03CMTH51	Real Analysis - II	Employability	T	4	3	30/10	70/28	100/40
	PS03CMTH52	Mathematical Methods - I	Employability	T	4	3	30/10	70/28	100/40
	PS03CMTH53	Functional Analysis - II	Employability	T	4	3	30/10	70/28	100/40
	PS03CMTH54	Comprehensive Viva	Employability,	T/P	1	3	-	50/20	50/20
Elective Courses	PS03EMTH51	Banach Algebras	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH52	Python Programming and Mathematical Algorithms	Employability, Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS03EMTH53	Graph Theory - II	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH54	Advanced Group Theory	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH55	Number Theory and Cryptography	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH56	Problems and Exercises in Mathematics - I	Employability, Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS03EMTH57	Problems and Exercises in Mathematics - II	Employability, Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS03EMTH58	Theory of Special Relativity	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH59	Mathematical Probability Theory	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH60	Special Functions-I	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH61	Approximation Theory	Employability	T	4	3	30/10	70/28	100/40
	PS03EMTH62	Mathematical Modelling	Employability	T	4	3	30/10	70/28	100/40
					25		180	470	650

(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (III)

Course Code	PS03CMTH51	Title of the Course	Real Analysis II
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	The aim of this course is to aware the students about the general Lebesgue measure theory and general Lebesgue integration theory.

Course Content		
Unit	Description	Weightage* (%)
1.	Measure space, finite, σ-finite, complete measures, measurable functions, simple functions, integration, Fatou's Lemma, Monotone Convergence Theorem, Lebesgue's dominated Convergence Theorem, Bounded Convergence Theorem.	25
2.	Signed measure, Hahn decomposition, Jordan decomposition, Lebesgue decomposition with examples, Radon-Nikodym theorem, Radon-Nikodym derivatives.	25
3.	$L^p(\mu)$ $(1 \leq p \leq \infty)$, Holder's inequality, Minkowski inequality, Riesz-Fischer Theorem, Completeness of $L^p(\mu)$, dual of $L^p(\mu)$, Riesz representation theorem.	25
4.	Outer measure and measurability, measure on an algebra, outer measure induced by a measure (on an algebra), Caratheodory's extension theorem, Baire measure, cumulative distribution function.	25

Teaching-Learning Methodology	Classroom teachimg.

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: Having completed this course, the learner will be able to	
1.	understand the concepts related to general Lebesgue measure and general Lebesgue integration which might be useful in probability theory and in applied mathematics.
2.	become aware about extension of a measure on an algebra.
3.	analyse that every cumulative distribution functions generates a Baire measure.

Suggested References:	
Sr. No.	References
1.	Royden, H. L., Real Analysis (Third Edition) Mc. Millan, 1998.
2.	De Berra, G., Introduction to Measure Theory, van-Nordstrand, 1974.
3.	Halmos, P. R., Measure Theory, Van-Nordstrand, 1970.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03CMTH52	Title of the Course	Mathematical Methods I
Total Credits of the Course	4	Hours per Week	4 hours

Course Objective	The objective of this paper is to formulate various problems and analyse their behaviour. Speciallyto learn Fundamental continuous and Discrete transforms.

Course Content		
Unit	Description	Weightage* (%)
1.	**Fourier Series and Applications** Fourier series, Euler's formulae, Conditions for a Fourier expansion, Functions having points of discontinuity, Change of interval, Odd and even functions, half range series, Parseval's Identity and applications, Complex form of Fourier series, Applications to boundary value problems: The Dirichlet interior problem for a circle, The Dirichlet exterior problem for a circle, The Neumann problem for a circle, The Dirichlet problem for a rectangle.	25
2.	**Fourier Transforms and Applications** The Fourier integral formulas, Definition of the Fourier transform and examples, Basic properties of Fourier transforms, Applications of Fourier transforms, Solutions ofpartial differential equations, Fourier cosine and sine transforms with examples, Properties of Fourier cosine and sine transforms, Applications of Fourier cosine and sine transforms to partial differential equations, Evaluation of definite integrals.	25
3.	**Laplace Transforms and Applications** Definition of the Laplace transform and examples, Basic properties of Laplace transforms, Convolution theorem and properties of convolution, Differentiation and Integration of Laplace transforms, The inverse Laplace transform and examples,	25

	Applications of Laplace transforms: Solutions of ordinary differential equations, Solutions of integral equations, Partial differential equations, Initial and boundary value problems Evaluation of definite integrals, exercise.	
4.	**Z-transforms and Applications** Definition of Z-transform and examples, Basic operational properties of Z-transform, The inverse Z-transform and examples, Applications of Z-transforms to finite difference equations, Summation of infinite series.	25

Teaching-Learning Methodology	Interaction based classroom teaching

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 Quizzes, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: After completion of this course, student will be acquainted to	
1	understand about Fourier series and their applications in mathematical physics.
2	analyse the behaviour of various problems with boundary conditions.
3	deliberate Fourier transforms, Fourier Integral formulae with applications to solve definite integrals.
4	explore the real-life problems through the concepts of Laplace transforms.
5	Z-transforms and related properties.

Suggested References:

Sr. No.	**Reference Books**
1.	B. S. Grewal, Higher Engineering Mathematics, Khanna Publishers, New Delhi 2004.
2.	Amarnath T., Elementary Course in Partial Differential Equations, Narosa Publ. House, New Delhi, 1997.
3.	Debnath, Lokenath; Bhatta, Dambaru, Integral transforms and their applications. Second edition. Chapman & Hall/CRC, Boca Raton, FL 2007.
4.	K. SankaraRao, Introduction to Partial Differential Equations, Prentice Hall India Learning Pvt. Ltd., Third Edition, 2011.
5.	M. D. Raisinghania, Advanced Differential Equations, S Chand Publishing 1995.
6.	Georgi P. Tolstov, Fourier Series, (Translated from Russian by R. A. Silverman), Dover Publications Inc., New York, 1976.

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

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(Master of Science) (Mathematics)
(M. Sc.) (Mathematics) Semester (III)

Course Code	PS03CMTH53	Title of the Course	Functional Analysis II
Total Credits of the Course	4	Hours per Week	04 (Four)

Course Objectives:	1. Students will study fundamental aspects of Banach Spaces 2. Students will learn four important classical theorems- Hahn-Banach Theorem, Uniform Boundedness principle, Closed graph theorem & Open mapping theorem. 3. This course will lead to do research in many directions of Analysis.

Course Content		
Unit	Description	Weightage* (%)
1.	Normed linear spaces (examples & basic properties), Holder-Minkowski inequalities, Bounded linear transformations, Space of bounded linear transformations.	25
2.	Hahn-Banach Extension Theorem, Strict convexity and uniqueness of Hahn-Banach extension, Banach spaces, Examples of Banach spaces.	25
3.	Uniform boundedness principle (consequences and examples), Closed graph Theorem, Projections, Open mapping Theorem, Bounded inverse theorem.	25
4.	Duals and transposes, dual of l^p, Weak convergence and Weak* convergence, their basic properties, Relation between weak, weak* and norm convergence, Bolzano-Weierstrass property (Banach-Alaoglu Theorem).	25

Teaching-Learning Methodology	Class room teaching

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

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

Course Outcomes: Having completed this course, the learner will be able to	
1.	realize that continuity (Topology) & linearity (Linear Algebra) can be related and both together gives very strong results.
3.	know that for finite dimensional space, many concepts coincide and many results become equivalent.
4.	aware to different sub branches of Analysis (For example, Banach algebras, Operator theory etc.), to pursue their research work.

Suggested References:

Sr. No.	References
1.	B. V. Limaye, Functional Analysis, New Age International (P) Ltd., 2001.
2.	V. K. Krishnan, Text book of Functional Analysis; A problem-oriented approach, Prentice Hall of India, 2014.
3.	Thamban Nair, Functional Analysis-a first course, Prentice Hall of India, 2002.
4.	S. Ponnusamy, Foundations of Functional Analysis, Narosa Pub. House, 2004.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH51	Title of the Course	Banach Algebras
This course is same as the course PS04EMTH53. The students opting for this course shall not be offered PS04EMTH53.			
Total Credits of the Course	04	Hours per Week	04 hours

Course Objectives:	1. To introduce one of the most important branches of Functional Analysis. 2. To apply this theory in Harmonic Analysis and Operator Theory.

Course Content		
Unit	Description	Weightage* (%)
1.	Basic definitions on algebras and Banach algebras, Examples of Banach algebras with different products and norms, Invertible elements and their properties, singular elements, Topological divisors of zero (TDZ), Some results on TDZ.	25
2.	Spectrum, Spectral radius, Resolvent set, Resolvent function, Resolvent equation, Spectral mapping theorem for polynomials, Spectral radius formula, Gelfand-Mazur Theory, Maximal left ideals, radical and semisimplicity.	25
3.	Complex homomorphisms, Gelfand topology and Gelfand space, Compactness of Gelfand space, Gelfand transform of an element, Gelfand representation (map), Examples of Gelfand space.	25
4.	Banach *-algebras, C*-algebras, Examples of Banach *-algebras, Self-adjoint elements and their properties, Stone-Weierstrass theorem, Gelfand-Neumark theorem for commutative C*-algebras, Closed ideals in C(X).	25

Teaching-Learning Methodology	Classroom teaching, Presentation by students, Supply of information about online resources

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 Quizzes, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: Having completed this course, the learner will be able to	
1.	learn a special but large class of Banach space theory.
2.	apply complex analysis and functional analysis theory.

Suggested References:

Sr. No.	References
1.	Kaniuth E., A Course in Commutative Banach Algebras, Springer, New York, 2009.
2.	Larsen R., Banach Algebras, Marcell-Dekker, 1973.
3.	Simmons G.F., Introduction to Topology and Modern Analysis, McGraw-Hill Co., Tokyo, 1963.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH52	Title of the Course	Python Programming and Mathematical Algorithms
This course is same as the course PS04EMTH54. The students opting for this course shall not be offered PS04EMTH54.			
Total Credits of the Course	04	Hours per Week	06

Course Objectives:	1. Learning a programming language and logical reasoning 2. Acquire skills in python

Course Content		
Unit	Description	Weightage* (%)
1.	The Basics: Literal constants, numbers, strings, variables, identifier naming, data types, objects, logical and physical lines, indentation. Operators, operator precedence, expressions. Control flow: the if statement, the while statement, the for loop, the break statement, the continue statement.	25
2.	Functions: Defining a function, local variables, default argument values, keyword arguments, the return statement, DocStrings. Modules: using the sys module, the from import statement, creating modules, the dir function.	25
Practicals	Purpose of python programs: 1. To find the minimum and maximum of a given list of numbers. 2. To check whether a given number is odd or even. To check whether a given year is a leap year or not. 3. To find the real roots of a quadratic equation. 4. To compute n!, power of some number a, sum and average of a list of numbers. To prepare the result of a student. 5. Primality lists: To check whether a given number is prime or not, to list all the prime numbers within a given range, to factorize a number. 6. Manipulation of numbers: to check whether a given number is perfect or not, to check whether a given number is palindrome or not, to compute the sum of digits of a given number, to compute the sum of squares of the digits, to print a given number in reverse order of its digits. 7. To compute GCD and LCM of two numbers, to evaluate the number theoretic functions like number of divisors, sum of divisors, Euler's totient function, Mobius function for a given positive integer n.	50

	8. To generate Fibonacci sequence and Lucas sequences; to compute the sum of the series and hence evaluate exp(x), sin(x), cos(x), tan(x), sinh(x), cosh(x) (terminate the program after n terms of the series or terminate the program at the desired level of accuracy).	

Teaching-Learning Methodology	Classroom teaching, use of ICT, Computer Lab work

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: Having completed this course, the learner will be able to	
1.	develop programming capability.
2.	formulate algorithms of some mathematical problems and solve them using programming.
3.	enhance their future research work with programming skills.
4.	capability to learn java and such other programming languages, and software applications with ease.

Suggested References:	
Sr. No.	References
1.	Swaroop C. H., A byte of Python, ebshelf Inc. , 2013
2.	James Payne, Beginning Python: Using Python 2.6 and Python 3, Wiley India, 2010.

3.	Amit Saha, Doing Math with Python, No Starch Press, 2015 .

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

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(Master of Science) (Mathematics)
(M. Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH53	Title of the Course	Graph Theory II
This course is same as the course PS04EMTH52. The students opting for this course shall not be offered PS04EMTH52.			
Total Credits of the Course	4	Hours per Week	04

Course Objectives:	1. Students will study applications of Graph Theory in various directions. 2. Students can solve real life problems using the topics like network, Shortest path problem. 3. Students will know that spectral properties of some matrices can be easily obtained by graph representation of matrices.

Course Content		
Unit	Description	Weightage* (%)
1.	Eigen values of graphs: Definition & basic properties, examples, eigen values of bipartite graphs, eigen values & graph parameters- Diameter, $\Delta(G)$ and $\delta(G)$, chromatic number, regularity & connectedness.	25
2.	Network: Flows and cuts, maximal flow, Min-max theorem. Ramsey theory: The Pigeonhole principle & its applications, Ramsey number-definition, graph theoretic representation for $r = 2$, Ramsey's theorem (Equivalent statements), lower and upper bound for Ramsey number.	25
3.	Enumeration of Trees: Cayley's formula, degree sequence of graphs. Spanning Trees in graphs: Contraction by edge, matrix-tree theorem. Decomposition and graceful labeling.	25
4.	Minimum spanning trees: Kruskal's algorithm, Prim's algorithm. Shortest Path Problems: Breadth First Search algorithm, Back-tracking algorithm, Dijkstra's algorithm for weighted graphs.	25

Teaching-Learning Methodology	Class room Teaching

Evaluation Pattern

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

Course Outcomes: Having completed this course, the learner will be able to	
1.	connect matrices & graphs and they can find spectral properties of matrices using graph parameters and vice-versa.
2.	solve real life problem like network problem using digraphs.
3.	know that some Number theory problems can be solved using graphs.
4.	solve practical problem like how to find out shortest distance path between two centres.

Suggested References:

Sr. No.	References
1.	Douglas B. West: Introduction to Graph Theory, Pearson Education, Inc., India, 2001.
2.	John Clark and D. A. Holton: A First look at Graph Theory, Allied Publishing Ltd., 1991.
3.	Narsingh Deo: Graph Theory with applications to Engg. And Computer Science, Prentice-Hall of India Pvt. Ltd., New Delhi, 1999.
4.	Russell Merris, Graph Theory, Wiley-Inter science, John Wiley & Sons, Inc., 2001.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH54	Title of the Course	Advanced Group Theory
This course is same as the course PS04EMTH57. The students opting for this course shall not be offered PS04EMTH57.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. Students will give an exposure to advanced results in the theory of groups like Cauchy's theorem, Cayley's theorem, Sylow's theorem, and classification of finite abelian groups. 2. Students will enhance problem solving ability applying the theory of groups.

Course Content		
Unit	Description	Weightage* (%)
1.	Definition of a group, some examples of groups, some preliminary lemmas, subgroups, Lagrange's theorem, Euler's theorem, Fermat's theorem, counting principle, the condition for HK to be a subgroup, order of HK, normal subgroups, and quotient groups, characterizations of normal subgroups, homomorphism, isomorphism, first isomorphism theorem, simple group, Cauchy's theorem for abelian groups, relation of two homomorphic groups.	25
2.	Automorphism, inner automorphism, Cayley's theorem and its applications, permutation groups, permutation as a product of disjoint cycles and transpositions, even and odd permutations, alternating group, another counting principle, conjugate classes, class equation and its applications, Cauchy's theorem (general case), number of conjugate classes in permutation group.	25
3.	Sylow's theorem, first proof, definition of p-Sylow subgroup, second proof of Sylow's theorem, double cosets and its order, existence of p-Sylow subgroup in subgroups, second part of Sylow's theorem, number of p-Sylow subgroups in a group, third part of Sylow's theorem, examples based on Sylow's theorems.	25
4.	Direct products, external direct product and internal direct product, properties of internal direct product, finite abelian groups as direct product of cyclic groups, invariants of an abelian group of order power of prime p, the subgroup $G(s)$ of an abelian group G, for an integer s for a prime p, uniqueness of invariants, number of non-isomorphic abelian groups of a given order.	25

Teaching-Learning Methodology	Classroom teaching, problem solving, independent reading

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: Having completed this course, the learner will be able to	
1.	gain better understanding of permutation groups and their applications.
2.	express a given finite abelian group as the direct product of cyclic groups and, given two direct products of cyclic groups, determine whether or not they are isomorphic.
3.	solve problems using class equation and Sylow's theorems.

Suggested References:	
Sr. No.	References
1.	Herstein, I. N., Topics in Algebra, (Second Edition), Wiley Eastern Ltd., New Delhi, 1975.
2.	Fraleigh J. B., A First Course in Abstract Algebra (Third Edition), Narosa, 1983.
3.	Gallian J. A., Contemporary Abstract Algebra (Fourth Edition), Narosa, 2008.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH55	Title of the Course	Number Theory and Cryptography
This course is same as the course PS04EMTH59. The students opting for this course shall not be offered PS04EMTH59.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. To enable students to learn the fundamental concepts of cryptography. 2. To understand the number theoretic foundations of modern cryptography and the principles behind their security. 3. To introduce advanced mathematical concept of elliptic curves and its applications in the Elliptic Curve Cryptography (ECC).

Course Content

Unit	Description	Weightage* (%)
1.	Number Theory and Discrete Logarithm Problem: Simple substitution ciphers (except cryptanalysis), divisibility and GCD, modular arithmetic, prime numbers, unique factorization and finite fields, primitive roots in finite fields. The discrete logarithm problem.	25
2.	DLP based cryptosystems: The Diffie-Hellman key exchange, the ElGamal public key cryptosystem, difficulty of discrete log problem (DLP), a collision algorithm for the DLP, the Chinese remainder theorem, the Pohlig-Hellman algorithm.	25
3.	The RSA Algorithm: Euler's formula and roots modulo pq, the RSA public key cryptosystem, implementation and security issues, primality testing, Pollard's p-1 factorization algorithm.	25
4.	Elliptic curve cryptography: Elliptic curves, elliptic curve over finite fields, the elliptic curve discrete logarithm problem, elliptic curve cryptography.	25

Teaching-Learning Methodology	Classroom teaching, problem solving, independent reading

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: Having completed this course, the learner will be able to	
1.	appreciate the application of number theory in cryptography.
2.	have a basic understanding of some cryptosystems, algorithms, their security protocols and various attacks on them.
3.	view the subject as a combination of algebra, number theory, geometry through the study of elliptic curves and elliptic curve cryptography.
4.	understand applications of Mathematics in data security.

Suggested References:

Sr. No.	References
1.	Hoffstein J., Pipher J., Silverman J. H., An Introduction to Mathematical Cryptography, Undergraduate Texts in Mathematics, Springer, New York, 2008.
2.	Douglas R. Stinson, Cryptograph: Theory and Practice, Second Edition, Chapman and Hall/CRC, 2005.
3.	N. Koblitz, A Course in Number Theory and Cryptography, Springer 1994.
4.	J. A. Buchmann, Introduction to Cryptography, Second Edition, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 2004.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH56	Title of the Course	Problems and Exercises in Mathematics I
This course is same as PS02EMTH54 and can be offered to the students who have not taken the course PS02EMTH54.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. Students will obtain a better understanding of the techniques of solving problems and exercises of analysis and abstract algebra. 2. Students will enhance the logical thinking, reasoning and problem-solving capability in analysis and abstract algebra.

Course Content		
Unit	Description	Weightage* (%)
1.	Sequences and series of real numbers, tests of convergence, limsup, liminf, power series, function of one variable: continuity, uniform continuity, differentiability, monotone functions, types of discontinuities of monotone functions, mean value theorem.	25
2.	Sequences and series of functions: uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, functions of several variables: directional derivative, partial derivative, derivative as a linear transformation.	25
3.	Vector spaces, subspaces, basis, dimension, linear transformations and matrices, rank, determinant, and trace of matrices, linear equations, eigenvalues and eigenvectors, Cayley-Hamilton theorem.	25
4.	Canonical forms, diagonal forms, diagonalization of matrices, triangular forms, Jordan forms. Quadratic forms, reduction and classification of quadratic forms. Inner product spaces, orthonormal basis.	25

Teaching-Learning Methodology	Classroom teaching, independent thinking, problem solving

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: Having completed this course, the learner will be able to	
1.	gain a problem-solving perspective in the subjects like analysis and abstract algebra.
2.	solve problems efficiently asked in various competitive exams in mathematics.

Suggested References:	
Sr. No.	References
1.	Rudin W., Principles of Mathematical Analysis (Third Edition), Tata MacGraw-Hill Publ., New Delhi, 1983.
2.	Ghorpade Sudhir R., and Limaye Balmohan V., A Course in Multivariate Calculus and Analysis, Springer 2010.
3.	Peter Olver and Chehrzad Shakiban, Applied Linear Algebra, 2nd Edition, Springer 2018.
4.	Seymour Lipschutz and Marc Lipson, Schaum's Outline of Linear Algebra, 4th Edition, McGraw Hill, 2008.
5.	K. Hoffman and Ray Kunje, Linear Algebra, Prentice-Hall of India private Ltd., 1971.

6.	I. N. Herstein, Topics in Algebra, Second edition, Wiley Eastern Ltd., 1975.

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (III)

Course Code	PS03EMTH57	Title of the Course	Problems and Exercises in Mathematics II
This course is same as the course PS04EMTH60. The students opting for this course shall not be offered PS04EMTH60.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. Students will obtain a better understanding of the techniques of solving problems and exercises of group theory, ring theory, complex analysis, ODE and PDE. 2. Students will enhance the logical thinking, reasoning and problem-solving capability in group theory, ring theory, complex analysis, ODE and PDE.

Course Content		
Unit	Description	Weightage* (%)
1.	Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems.	25
2.	Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain, Polynomial rings and irreducibility criteria, Fields, finite fields, field extensions, Galois Theory.	25
3.	Algebra of complex numbers, polynomials, power series, trigonometric and hyperbolic functions, analytic functions, Cauchy-Riemann equations, Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, Maximum modulus principle, Taylor series, Laurent series, calculus of residues, conformal mappings, Mobius transformations.	25
4.	Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations (ODE), system of first order ODE, Lagrange and Charpit's method for solving first order partial	25

	differential equations (PDE), Classification of second order PDE.	

Teaching-Learning Methodology	Classroom teaching, independent thinking, problem solving

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: Having completed this course, the learner will be able to	
1.	gain a problem-solving perspective in the subjects like group theory, ring theory, complex analysis, ODE and PDE.
2.	solve problems efficiently asked in various competitive exams in mathematics.

Suggested References:	
Sr. No.	References
1.	Gallian, J., Contemporary Abstract Algebra, (Eight Edition), Books/Cole Cengage Learning, Belmont, 2013.
2.	Dummit, D.S. and Foote, R.M., Abstract Algebra, (Third Edition), John Wiley & Sons Inc., 2004.
3.	Simmons G. F., Differential Equations with Applications and Historical Notes, (Second Edition), McGraw-Hill International Editions, 1991.

4.	Raisinghania M. D., Advanced Differential Equations, (Sixth Revised Edition), S. Chand, 2013.
5.	Churchil, R.V., Brown, J. and Verle, R., Complex Variables and Applications, McGraw-Hill Publ. Co., Eighth edition, 2009.
6.	Conway J.B., Functions of One Complex Variable, (Second Edition), Narosa Publ. House, New Delhi, 1994.
7.	Bak Joseph and Newman Donald J., Complex Analysis. Third edition. Undergraduate Texts in Mathematics, Springer, New York, 2010.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH58	Title of the Course	Theory of Special Relativity
This course is same as the course PS04EMTH63. The students opting for this course shall not be offered PS04EMTH63.			
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. The course is aimed at giving exposure to special relativity. 2. Learning application of advanced tools of non-Euclidean geometry. 3. Application of Mathematics to special relativity and electromagnetic theories. 4. Introduction to relativistic approach to electrodynamics

Course Content		
Unit	Description	Weightage* (%)
1.	Historical background, Galilean transformations, non-invariance of Maxwell's equations under Galilean transformation, postulates of special relativity, relativity of simultaneity, Michelson Morley experiment, Special Lorentz transformation, consequences of special Lorentz transformation, relativistic addition of velocities, General Lorentz transformation.	25
2.	Aberration of light (Newtonian and Relativistic), Doppler effect (Newtonian and Relativistic), space-time interval four dimensional formulation, Poincare structure of spacetime, Minkowski structure of spacetime.	25
3.	Covariance four dimensional form, principle of covariance, proper time, four dimensional vectors (Displacement, velocity), mass of moving particle, covariant form of Newtonian's laws, momentum 4-vector, relativistic kinetic energy, equivalence of mass and energy.	25
4.	Electric field, electrostatic potential, work and energy in electrostatics, magnetostatics, Lorentz force law and Biot-Savrat law, magnetic field and magnetostatic potential, Maxwell's equations for electrodynamics, potential formulation in electrodynamics, relativistic electrodynamics (Maxwell's equations and potentials).	25

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

Methodology	

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: Having completed this course, the learner will be able to	
1.	understand of role of mathematics to theories in other branches of science.
2.	use the basic knowledge of special relativity to relevant situations.
3.	use the phenomena of optics in the framework of relativity.
4.	understand of non-Euclidean geometry and will be able to apply it further to general relativity.

Suggested References:	
Sr. No.	References
1.	Resnick, R., Introduction to Special Relativity, Wiley (Student Edition), 2007.
2.	Griffiths D.J., Introduction to Electrodynamics, , Cambridge University Press (4th Edition , South Asia Edition), 2020
3.	Banerji, S. and Banerjee, A., The Special Theory of Relativity, Prentice-Hall of India, Delhi, 2012
4.	Schutz, B.F., A First Course in General Relativity, Cambridge University Press (2nd Edition), 2009
5.	Krori K.D., Fundamentals of Special and General Relativity, Prentice-Hall of India, Delhi, 2010

On-line resources:

1. NPTEL Course:
   https://www.youtube.com/watch?v=0nHovWsWZTw&list=PLRuWd0sgheSZLMfA9yl_-cYEW_QyRlssD
   (Search Key on YouTube: Special Relativity + NPTEL)
2. Khan Academy Series: https://www.youtube.com/watch?v=iAPYsOaq-VY&list=PLqwfRVlgGdFA9KZBxFNifmVG2l5FSdBJm
   (Search Key on YouTube: Special Relativity + Khan Academy)

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (III)

Course Code	PS03EMTH59	Title of the Course	Mathematical Probability Theory
This course is same as the course PS04EMTH58. The students opting for this course shall not be offered PS04EMTH58.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	Students will learn types of convergence sequence of random variables which might be useful in the study of random phenomena arising in the real world.

Course Content		
Unit	Description	Weightage* (%)
1.	Random variables, Vector random variables, Limits of random variables, Probability measure, General probability space, Induced probability space, Distribution function of random variable, Jordan Decomposition theorem.	25
2.	Distribution function of vector random variables, Distribution function of dense subset of R, Expectation, Properties of expectation, Expectation of complex random variables, C_r- Inequality, Holder's Inequality, Minkowski Inequality, Jensen's Inequality, Chebyshev's Inequality.	25
3.	Monotone convergence theorem, Fatou's theorem, Dominated convergence theorem, Convergence in probability, Weak law of large numbers, Convergence almost surely, Toeplitz lemma, Cronecker lemma,, Kolmogorov's Inequality, Strong law of large numbers (iid case), Convergence in distribution, Convergence in r^{th} mean.	25
4.	Characteristic function, Properties of characteristic function, Inversion formula, Helly's first and second theorems, Helly-Bray theorem, Levy's theorem (continuity theorem, Central limit theorem (Lindeberg-Levy's theorem) (iid case).	25

Teaching-Learning Methodology	Classroom teachimg.

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: Having completed this course, the learner will be able to	
1.	learn stochastic processes used in the mathematical models to study real world problems.
2.	construct mathematical models.

Suggested References:	
Sr. No.	References
1.	B. R. Bhat, Modern Probability Theory: An Introductory Textbook, New Age International Publishers, 4th edition, 2014.
2.	A. K. Basu, Measure Theory and Probability, Prentice Hall of India, 2nd edition, 2015.
3.	Robert B. Ash, Probability and Measure Theory, Academic press, 2^{nd} edition, 1999.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH60	Title of the Course	Special Functions-I
This course is same as the course PS04EMTH64. The students opting for this course shall not be offered PS04EMTH64.			
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	In this course, preliminary of the Special Functions will be covered which lead to the study of certain Special Functions.

Course Content

Unit	Description	Weightage* (%)
1.	Infinite products: definition, convergence, its association with series, absolute and uniform convergence. The Gamma and Beta functions: Weierstrass definition, Euler product formula, The difference equation $\Gamma(z+1) = z\,\Gamma(z)$, Series for $\Gamma'(z)/\Gamma(z)$; Beta function, the value of $\Gamma(z)\,\Gamma(1-z)$, Factorial function, Legendre duplication formula.	25
2.	Hypergeometric function ${}_2F_1[z]$: its convergence, Integral representation, Differential equation, Analyticity, ${}_2F_1[z]$ and its properties, Contiguous functions relations, Simple and quadratic transformations, Kummer's theorem for ${}_2F_1[-1]$.	25
3.	Generalized hypergeometric function ${}_pF_q[z]$: its convergence, Integral representation, Differential equation, Saalschütz's theorem, Whipple's theorem, Dixon's theorem.	25
4.	The Bessel function $J_n(z)$ as ${}_0F_1[z]$, Recurrence relations, Differential equation, A pure recurrence relation, A generating function, index half an odd integer, Bessel's integral, Modified Bessel function.	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: Having completed this course, the learner will be able to	
1.	understand the core concepts of infinite products, gamma and beta functions.
2.	derive the properties of special functions along with their existence and form an alternate representation of them.
3.	describe and analyse the generalized Hypergeometric function and the Bessel functions along with their properties in a researched based problem.
4.	transform a hypergeometric function to another hypergeometric function.

Suggested References:

Sr. No.	References
1.	Rainville, E. D., Special Functions, Macmillan Co., New York, 1960.
2.	Andrews, G. E., Askey, R. and Ranjan Roy, Special Functions, Cambridge University Press, 1999.
3.	Slater, L. J., Generalized Hypergeometric Functions, Cambridge University Press, Cambridge, NY, 1966.
4.	Wang, Z. X. and Guo, D. R., Special Functions, World Scientific Publ., Singapore, 1989.
5.	Andrews, L. C., Special Functions of Mathematics for Engineers, McGraw Hill Book Co, 1998.
6.	Watson, G. N., A treatise on the theory of Bessel functions, Cambridge University Press, Cambridge, UK, 1996.

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (III)

Course Code	PS03EMTH61	Title of the Course	Approximation Theory
Total Credits of the Course	04	Hours per Week	04
This course is same as PS04EMTH66 and can be offered to the students who have not taken the course PS04EMTH66.			

Course Objectives:	1. Students will obtain a better understanding of approximating continuous functions using the various techniques. 2. Students will enhance the idea on density theorems using positive linear operators.

Course Content		
Unit	Description	Weightage* (%)
1.	**Basics of Approximation Theory:** Introduction, Function Spaces, Convex and Strictly Convex Norms, The best approximation, Existence and uniqueness of best approximation (Finite-dimensional subspaces, Strictly convex spaces), Examples of nonexistence, Density theorems etc. A brief Introduction to: Classical approximation, Abstract approximation, Constructive approximation etc.	25
2.	**Approximation by Algebraic and Trigonometric Polynomials:** Approximation by Algebraic Polynomials: Uniform Approximation by Algebraic Polynomials, the First Weierstrass Theorem, Degree of approximation, Lipschitz classes, Different types of modulus of continuity. Approximation by Trigonometric Polynomials: The second Weierstrass Theorem, the Chebyshev Polynomials, Pointwise convergence and uniform convergence, Estimates with Second Order Moduli, Absolute Optimal Constants.	25
3.	**Positive Linear Operators** Positive linear operators and functionals; Chebyshev conditions to choose test functions, the Bohman-Korovkin Theorem, Bernstein operators, Estimates for the Bernstein Operators, Bernstein inequality, Improved Estimates, Lupas and Phillips operators (Quantum and Post	25

	quantum analogue)	
4.	**Jackson's Theorems, Approximation by Rational Functions**: A brief Introduction to Interpolation (Lagrange interpolation formula, Error bounds for Lagrange interpolation, Peano kernel), Chebyshev points and interpolants, Chebyshev polynomials and series, Barycentric interpolation formula, The Inequalities of Markov and Bernstein. Direct Theorems, Inverse Theorems, Convergence for differentiable functions, Convergence for analytic functions, Approximation by Rational Functions, Nonlinear approximation (why rational functions?), Rational best approximation, Pade approximation.	25

Teaching-Learning Methodology	Classroom teaching, independent thinking, problem solving

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: Having completed this course, the learner will be able to	
1.	Gain techniques of approximating continuous functions using rational function, polynomials and sequence of positive linear operators.
2.	Clear concept of the existence and uniqueness of best approximation.
3.	Clear concept of the Uniform Approximation by Algebraic Polynomials, Approximation by Trigonometric Polynomials.
4.	Clear concept of how to deal with Jackson's Theorems and various method of approximation methods.

Suggested References:	
Sr. No.	References
1.	Fundamentals of Approximation Theory, Hrushikesh N. Mhaskar, Devidas V. Pai CRC Press, 2000
2.	N. L. Carothers, A Short Course on Approximation Theory, Department of Mathematics and Statistics, Bowling Green State University.
3.	Lloyd N. Trefethen, Approximation Theory and Approximation Practice, Society for Industrial and Applied Mathematics Philadelphia, PA, USA, 2012.
4.	M J D Powell, Approximation theory and methods, 1981 (CUP, reprinted 1988).
5.	R. DeVore, G.G. Lorentz, Constructive Approximation, Springer Verlag, 1993.
6.	E. W. Cheney, An Introduction to Approximation Theory, 2nd ed., New York: Chelsea, 1982
7.	Pyramid Algorithms, A Dynamic Programming Approach to Curves and Surfaces for Geometric Modeling, R Goldman, Elsevier-2002.
8.	P. P. Korovkin, Linear operators and approximation theory, Hindustan Publishing Corporation, Delhi, 1960.
9.	Radu Paltanea, Approximation Theory Using Positive Linear Operators, Birkhauser Springer2004.
10.	Intelligent Systems: Approximation by Artificial Neural Networks, George A. Anastassiou, Springer, 2011.
11	Intelligent Systems II: Complete Approximation by Neural Network Operators, George A. Anastassiou, Springer, 2016.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (III)

Course Code	PS03EMTH62	Title of the Course	Mathematical Modelling
This course is same as the course PS04EMTH67. The students opting for this course shall not be offered PS04EMTH67.			
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. The course is aimed at giving exposure to Mathematical modelling. 2. Apply difference equations and differential equations in solving some real world problems.

Course Content

Unit	Description	Weightage* (%)
1.	**Introduction to Mathematical Modelling** Motivation, Modelling process, Linear and Non-linear difference equations, Equilibrium and Stability, Linear and Non-linear difference models, Mathematical Modelling Through Ordinary Differential Equations of First Order, Linear and Non-linear Growth and Decay Models, Electrical circuits, Compartment Models, Others	25
2.	**Mathematical Modelling Using System of First Order Ordinary Differential Equations** Steady State Solutions, Linearization and Local Stability Analysis, Population Dynamics, Epidemics, Medicine, Economics, Arms Race, Battles, Others	25
3.	**Mathematical Modelling in Celestial Dynamics Through Second Order Ordinary Differential Equations** Two Body Central Force Problem, Differential Equation of Orbit, Modelling of Planetary Motions, Circular Motion of Satellites, Electrical Circuits, Others	25
4.	**Mathematical Modelling using Partial Differential Equations** Fluid Flow Through Porus Medium, Heat Flow Through a Small Thin Rod, Wave Equation, Vibrating String, Vibrating Membrane, Traffic Flow, Others	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: Having completed this course, the learner will be able to	
1.	Formulate mathematical models related to Population, Newton's law of cooling, Drug delivery problem, Arms race, Economic Model, etc. using difference equation and solve them.
2.	Using first order differential equation and system of first order ordinary differential equation make mathematical model of Linear and Non-linear Growth and Decay Models, Carbon Dating, Drug distribution in body, Electrical circuits, Compartment Models and solve them.
3.	Make some mathematical models using second order ordinary differential equation and solve them.
4.	Mathematical modelling using partial differential equation for Fluid flow through porus medium, Heat flow through a small thin rod, Wave equation, Vibrating String, Traffic flow.

Suggested References:	
Sr. No.	References
1.	S. Banerjee, Mathematical modelling, CRC Press, Taylor and Francis Group, 2014.
2.	J.N. Kapur, Mathematical modelling, New Age International Publication, Second Edition, 2021.
3.	M. Braun, C.S. Coleman and D.A. Drew, Differential equation modes, Springer, 1994.
4.	Z. Ahsan, Differential Equations and their applications, Third Edition, PHI, 2016.

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SARDAR PATEL UNIVERSITY
(Under the Choice based Credit Scheme)
STRUCTURE WITH EFFECT FROM:2022-23
M.Sc. (Mathematics) Semester - 4

Course Type	Course Code	Name of Course	Focus on Employability/ Skill Development/ Entrepreneurship	T /P	Credit	Exam Duration in hrs	Component of Marks		
							Internal	External	Total
							Total/ Passing	Total/ Passing	Total/ Passing
Core Courses	PS04CMTH51	Complex Analysis - II	Employability	T	4	3	30/10	70/28	100/40
	PS04CMTH52	Mathematical Methods - II	Employability	T	4	3	30/10	70/28	100/40
	PS04CMTH53	Comprehensive Viva	Employability	T/P	1	-	-	50/20	50/20
Elective Courses	PS04EMTH51	Topology - II	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH52	Graph Theory - II	Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS04EMTH53	Banach Algebras	Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS04EMTH54	Python Programming and Mathematical Algorithms	Employability, Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS04EMTH55	Financial Mathematics	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH56	Theory of General Relativity	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH57	Advanced Group Theory	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH58	Mathematical Probability Theory	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH59	Number Theory and Cryptography	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH60	Problems and Exercises in Mathematics - II	Employability, Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS04EMTH61	Operator Theory	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH62	Problems and Exercises in Mathematics - III	Employability, Skill Enhancement	T	4	3	30/10	70/28	100/40
	PS04EMTH63	Theory of Special Relativity	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH64	Special Functions-I	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH65	Special Functions-II	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH66	Approximation Theory	Employability	T	4	3	30/10	70/28	100/40
	PS04EMTH67	Mathematical Modelling	Employability	T	4	3	30/10	70/28	100/40
					25		180	470	650

(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04CMTH51	Title of the Course	Complex Analysis II
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. To introduce students to Riemann Stieltjes integral and study the theory of complex integration over rectifiable curves. 2. To study the spaces of continuous functions and analytic functions on a region of the complex plane. 3. To study important results of complex analysis like Identity theorem, Counting Zero Principle, Argument Principle, Rouche's theorem, Schwarz's lemma, etc.

Course Content

Unit	Description	Weightage* (%)
1.	Riemann Stieltjes integral: a function of bounded variation on $[a, b]$, its total variation, rectifiable curve, smooth curve, piecewise smooth curve, polygonal path, integral of a continuous function on $[a, b]$ with respect to a function of bounded variation and its properties, integral of continuous function defined on $\{\gamma\}$ with respect to γ and its properties, zeros of an analytic function, multiplicity of zero of an analytic function, the index of a closed curve and its properties.	25
2.	Cauchy's Theorem (First version), Cauchy's Integral Formula (First and Second Version), Cauchy's Integral formula for derivatives, Morera's Theorem, existence of a primitive on simply connected region, characterization of non-vanishing analytic function on simply connected region, Counting zero principle and open mapping theorem, Classification of singularities namely removable singularity, pole and essential singularity, order of a pole, Casorati-Weierstrass theorem.	25
3.	Argument Principle, its generalization and examples, Rouche's theorem and deduction of Fundamental Theorem of Algebra, Maximum Modulus principle (statements only), Schwarz's lemma, its applications and consequences, Mobius transformation φ_a and its properties, the space of continuous functions $C(G, \Omega)$, the topology on $C(G, \Omega)$, normal family in $C(G, \Omega)$, equicontinuity of a family in $C(G, \Omega)$, Arzela Ascoli theorem in $C(G, \Omega)$.	25
4.	The space $H(G)$ of analytic functions, locally bounded family in $H(G)$, Hurwitz's therorem, Montel's theorem, infinite product, convergence and absolute convergence of infinite product, convergence of infinite product of elements in $H(G)$, elementary factors and its properties, The	25

	Weierstrass Factorization Theorem, factorization of sin, cos, sinh and cosh, Walli's formula.	

Teaching-Learning Methodology	Classroom teaching, problem solving, independent learning

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: Having completed this course, the learner will be able to	
1.	develop problem solving techniques using the results like Identity theorem, Argument principle, Rouche's theorem, etc.
2.	understand the theory of complex integration in great generality, to understand the space of analytic functions and its significance.
3.	become capable to understand the applications of Complex Analysis techniques in different fields.

Suggested References:	
Sr. No.	References
1.	J. B. Conway, Functions of One Complex Variable, 2nd Edition, Narosa, New Delhi, 1978.
2.	W. Rudin, Real and Complex Analysis, McGraw Hill, 1967.
3.	R. Narasimhan and Y. Nievergelt, Complex Analysis in One Variable, Birkhauser, 2001.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04CMTH52	Title of the Course	Mathematical Methods II
Total Credits of the Course	4	Hours per Week	4 hours

Course Objective	The objective of this paper is to formulate various problems and analyse their behaviour of system. Significantly to learn concepts of Mathematical Physics also.

Course Content

Unit	Description	Weightage* (%)
1.	**Calculus of Variations** Functional, Euler's equation, Other forms of Euler's equation, Special cases of Euler's equation, Geodesics, Isoperimetric problems, Several dependent variables, Functional involving higher order derivatives.	25
2.	**Volterra Integral Equations** Types of integral equations, Volterra Integral Equations, Conversion of differential equation into an integral equation, Conversion of integral equation into a differential equation, Solution verification, Solution of Volterra Integral equation, Abel's integral equations, Integro-differential equation.	25
3.	**Fredholm Integral Equations** Compact operators on $C[a,b]$ and $L^p[a,b]$, Fredholm alternative theorems, Types of Fredholm integral equations, Types of kernels viz. Separable, Symmetric, Iterated, Resolvent, Solution of Fredholm integral equations.	25
4.	**Sturm-Liouville Differential Equations and Green Functions** Sturm-Liouville equation, Conversion of well-known differential equations into Sturm-Liouville differential equation, Conversion of differential equations into well-known differential equations,	25

	Rodrigues' formulae of well-known polynomials and their special cases, Solution of Sturm-Liouville differential equation, Green's Function and its applications.	

Teaching-Learning Methodology	Interaction based Classroom teaching

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 Quizzes, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: After completion of this course, student attentive with	
1	understanding about functionals and their applications in mathematical physics.
2	analysing the behaviour of various problems with boundary conditions.
3	deliberate conversion of integral and differential equations
4	explore the solution of linear integral equations by analysing various kernels.
5	some standard differential equations (viz. Bessel, Legendre, Laguerre, Chebyshev, Hermite) to Sturm-Liouville equation

Suggested References:	
Sr. No.	**Reference Books**
1.	B. S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 43rd Edition, Delhi, 2012.
2.	A. S. Gupta, calculus of variations with applications, Prentice-Hall of India, New Delhi, 1999.

3.	B. V. Limaye, Functional analysis, 2nd Edition, New Delhi, 1996.
4.	A. L. Rabenstein, Introduction to Ordinary Differential Equations, Academic Press, London, 1972.
5.	E.D.Rainville, Special Functions, Macmillan Co. 1960.

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

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(Master of Science) (Mathematics)
(M. Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH51	Title of the Course	Topology II
Total Credits of the Course	4	Hours per Week	04 (Four)

Course Objectives:	1. Students will learn advance level concepts in Topology, like net, filter, infinite product etc. 2. Students will study generalization of sequence, limit.

Course Content		
Unit	Description	Weightage* (%)
1.	Neighbourhoods, neighbourhood base at a point, Product spaces and the weak topology Inadequacy of sequences, directed set, net, convergence and clustering of a net, characterization of closure and continuity using net, subnet, ultranet.	25
2.	Filter, filter base, convergence and clustering of a filter, finer filter, ultra filter, free and fixed filter, characterization of closure and continuity using filter.	25
3.	Filter generated by a net, a net based on a filter, and their convergence. Characterization of compact spaces using nets and filters, Tychonoff Theorem.	25
4.	Homotopy of functions from one topological space to another, path homotopy, product of two paths and its algebraic structure, loop, Fundamental group relative to the base point, isomorphism of fundamental groups, simply connected space, homomorphism induced by a continuous map.	25

Teaching-Learning Methodology	Class room Teaching

Evaluation Pattern		
Sr.No.	Details of the Evaluation	Weightage

1.	Internal Written Examination (As per CBCS R.6.8.3)	15%
2.	Internal Continuous Assessment in the form of Quizzes, Seminars, Assignments, Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: Having completed this course, the learner will be able to	
1.	generalize some standard topological concepts.
2.	know some more advance level ideas and results.
3.	realize that some standard results do not remain true in generalization.

Suggested References:

Sr. No.	References
1.	Willards, S., General Topology, Dover Publication, New York, 1970.
2.	Munkres, J., Topology: A First Course, 2/e, Prentice Hall of India Pvt. Ltd. New Delhi, 2003.
3.	Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw-Hill Co., Tokyo, 1963.

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

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(Master of Science) (Mathematics)
(M. Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH52	Title of the Course	Graph Theory II
This course is same as PS03EMTH53 and can be offered to the students who have not taken the course PS03EMTH53.			
Total Credits of the Course	4	Hours per Week	04

Course Objectives:	1. To study applications of Graph Theory in various directions. 2. Students can solve real life problems using the topics like network, Shortest path problem. 3. Students will know that spectral properties of some matrices can be easily obtained by graph representation of matrices.

Course Content		
Unit	Description	Weightage* (%)
1.	Eigen values of graphs: Definition & basic properties, examples, eigen values of bipartite graphs, eigen values & graph parameters- Diameter, $\Delta(G)$ and $\delta(G)$, chromatic number, regularity & connectedness.	25
2.	Network: Flows and cuts, maximal flow, Min-max theorem. Ramsey theory: The Pigeonhole principle & its applications, Ramsey number-definition, graph theoretic representation for $r = 2$, Ramsey's theorem (Equivalent statements), lower and upper bound for Ramsey number.	25
3.	Enumeration of Trees: Cayley's formula, degree sequence of graphs. Spanning Trees in graphs: Contraction by edge, matrix-tree theorem. Decomposition and graceful labeling.	25
4.	Minimum spanning trees: Kruskal's algorithm, Prim's algorithm. Shortest Path Problems: Breadth First Search algorithm, Back-tracking algorithm, Dijkstra's algorithm for weighted graphs.	25

Teaching-Learning Methodology	Class room Teaching

Evaluation Pattern

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

Course Outcomes: Having completed this course, the learner will be able to	
1.	connect matrices & graphs and they can find spectral properties of matrices using graph parameters and vice-versa.
2.	solve real life problem like network problem using digraphs.
3.	know that some Number theory problems can be solved using graphs.
4.	solve practical problem like how to find out shortest distance path between two centres.

Suggested References:

Sr. No.	References
1.	Douglas B. West: Introduction to Graph Theory, Pearson Education, Inc., India, 2001.
2.	John Clark and D. A. Holton, A First look at Graph Theory, Allied Publishing Ltd., 1991.
3.	Narsingh Deo: Graph Theory with applications to Engg. And Computer Science, Prentice-Hall of India Pvt. Ltd., New Delhi, 1999.
4.	Russell Merris, Graph Theory, Wiley-Inter science, John Wiley & Sons, Inc., 2001.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH53	Title of the Course	Banach Algebras
This course is same as PS03EMTH51 and can be offered to the students who have not taken the course PS03EMTH51.			
Total Credits of the Course	04	Hours per Week	04 hours

Course Objectives:	1. To introduce one of the most important branches of Functional Analysis. 2. To apply this theory in Harmonic Analysis and Operator Theory.

Course Content		
Unit	Description	Weightage* (%)
1.	Basic definitions on algebras and Banach algebras, Examples of Banach algebras with different products and norms, Invertible elements and their properties, singular elements, Topological divisors of zero (TDZ), Some results on TDZ.	25
2.	Spectrum, Spectral radius, Resolvent set, Resolvent function, Resolvent equation, Spectral mapping theorem for polynomials, Spectral radius formula, Gelfand-Mazur Theory, Maximal left ideals, radical and semisimplicity.	25
3.	Complex homomorphisms, Gelfand topology and Gelfand space, Compactness of Gelfand space, Gel'fand transform of an element, Gelfand representation (map), Examples of Gelfand space.	25
4.	Banach *-algebras, C*-algebras, Examples of Banach *-algebras, Self-adjoint elements and their properties, Stone-Weierstrass theorem, Gelfand-Neumark theorem for commutative C*-algebras, Closed ideals in C(X).	25

Teaching-Learning Methodology	Classroom teaching, Presentation by students, Supply of information about online resources

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 Quizzes, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: Having completed this course, the learner will be able to	
1.	learn a special but large class of Banach space theory.
2.	apply complex analysis and functional analysis theory.

Suggested References:	
Sr. No.	References
1.	Kaniuth E., A Course in Commutative Banach Algebras, Springer, New York, 2009.
2.	Larsen R., Banach Algebras, Marcell-Dekker, 1973.
3.	Simmons G.F., Introduction to Topology and Modern Analysis, McGraw-Hill Co., Tokyo, 1963.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH54	Title of the Course	Python Programming and Mathematical Algorithms
This course is same as PS03EMTH52 and can be offered to the students who have not taken the course PS03EMTH52.			
Total Credits of the Course	04	Hours per Week	06

Course Objectives:	1. Learning a programming language and logical reasoning 2. Acquire skills in python

Course Content		
Unit	Description	Weightage* (%)
1.	The Basics: Literal constants, numbers, strings, variables, identifier naming, data types, objects, logical and physical lines, indentation. Operators, operator precedence, expressions. Control flow: the if statement, the while statement, the for loop, the break statement, the continue statement.	25
2.	Functions: Defining a function, local variables, default argument values, keyword arguments, the return statement, DocStrings. Modules: using the sys module, the from import statement, creating modules, the dir function.	25
Practicals	Purpose of python programs: 1. To find the minimum and maximum of a given list of numbers. 2. To check whether a given number is odd or even. To check whether a given year is a leap year or not. 3. To find the real roots of a quadratic equation. 4. To compute n!, power of some number a, sum and average of a list of numbers. To prepare the result of a student. 5. Primality lists: To check whether a given number is prime or not, to list all the prime numbers within a given range, to factorize a number. 6. Manipulation of numbers: to check whether a given number is perfect or not, to check whether a given number is palindrome or not, to compute the sum of digits of a given number, to compute the sum of squares of the digits, to print a given number in reverse order of its digits. 7. To compute GCD and LCM of two numbers, to evaluate the number theoretic functions like number of divisors, sum of divisors, Euler's totient function, Mobius function for a given positive integer n.	50

	8. To generate Fibonacci sequence and Lucas sequences; to compute the sum of the series and hence evaluate exp(x), sin(x), cos(x), tan(x), sinh(x), cosh(x) (terminate the program after n terms of the series or terminate the program at the desired level of accuracy).	

Teaching-Learning Methodology	Classroom teaching, use of ICT, Computer Lab work

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: Having completed this course, the learner will be able to	
1.	develop programming capability
2.	formulate algorithms of some mathematical problems and solve them using programming
3.	enhance their future research work with programming skills
4.	capability to learn java and such other programming languages, and software applications with ease.

Suggested References:	
Sr. No.	References
1.	Swaroop C. H., A byte of Python, ebshelf Inc., 2013.
2.	James Payne, Beginning Python: Using Python 2.6 and Python 3, Wiley India, 2010.

3.	Amit Saha, Doing Math with Python, No Starch Press, 2015.

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (IV)

Course Code	PS04EMTH55	Title of the Course	Financial Mathematics
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	Financial mathematics mainly uses the modern mathematical theory and methods. So the students will learn mathematics used in finance.

Course Content		
Unit	Description	Weightage* (%)
1.	Types of financial derivatives, Exchange Traded (ET) markets, Over the Counter (OTC) markets, Forward contracts, Futures contracts, Options, Types of options, Types of traders: Hedgers, Speculators, Arbitrageurs, Uses of derivatives.	25
2.	Stochastic processes: Markov process, Wiener process, Generalized Wiener process, Simple model for stock price, Ito process, Ito's lemma.	25
3.	Log normal property of stock prices., The distribution of the rate of return, expected return, Derivation of Black-Schole-Merton (BSM) differential equation, Derivation of BSM formulas for European options through probabilistic approach.	25
4.	Analysis of BSM formulas, Derivation of Greek letters: Delta, Theta, Gamma, Vega, Rho, BSM formulas on an asset paying dividend, Examples.	25

Teaching-Learning Methodology	Teaching methods of this course include lectures in the classroom through black board or ICT.

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: Having completed this course, the learner will be able to	
1.	become aware about financial markets.
2.	get familiar with the celebrated BSM formula.

Suggested References:	
Sr. No.	References
1.	J. C. Hull and S. Basu, Options, Futures and Other Derivatives, 7th edition, Pearson Prentice Hall, 2011.
2.	S. M. Ross, An elementary introduction to mathematical finance, Cambridge Uni. Press, 3rd edition, 2011.
3.	P. Wilmott, S. Howison and J. Dewynne, The mathematics of financial derivatives, Cambridge Uni. Press, 1995.
4.	S. L. Gupta, Financial Derivatives: Theory, Concepts and Problems, Prentice Hall of India, 2005.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04CMTH56	Title of the Course	Theory of General Relativity
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. The course is aimed at giving exposure to general relativity. 2. Learning application of advanced tools of Riemannian geometry. 3. Application of Mathematics and general relativity to cosmology.

Course Content		
Unit	Description	Weightage* (%)
1.	Space-time fundamental tensors, Christoffel symbols, covariant derivative, Riemann tensor, Ricci tensor, Einstein tensors in general relativity. Energy-momentum tensor.	25
2.	Parallel transport, geodesic equation, gravity as geometric phenomena. Criteria for gravitational field equations, Einstein's field equations, Einstein-Maxwell's equations, metric for spherically symmetric space-times.	25
3.	Schwarzschild exterior solution, various forms of Schwarzschild solution. The general relativistic Kepler problem and crucial tests of GR, Kruskal coordinates and the black hole, Schwarzschild interior solution. Reissner-Nordstom solution.	25
4.	Relativistic cosmology: observational background, cosmological postulates, static models of the universe. Features of Einstein universe and de-Sitter universe. Limitations of static models.	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: Having completed this course, the learner will able to	
1.	understand the role of tensors in GR
2.	acquire the basic knowledge of general relativity.
3.	have various models of blackholes using GR.
4.	understand the basic models of the universe in the framework of GR.

Suggested References:	
Sr. No.	References
1.	Adler, R., Bazin, M. and Shiffer, M., Introduction to general relativity
2.	Zafar Ahsan,Tensors mathematics of differential geometry and general relativity. Narlikar,
3.	J.V., An Introduction to Cosmology, Cambridge University Press, Cambridge. 2002
On-line resources to be used if available as reference material	
On-line resources:	

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH57	Title of the Course	Advanced Group Theory
This course is same as PS03EMTH54 and can be offered to the students who have not taken the course PS03EMTH54.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. To give an exposure to advanced results in the theory of groups like Cauchy's theorem, Cayley's theorem, Sylow's theorem, and classification of finite abelian groups. 2. To enhance problem solving ability applying the theory of groups.

Course Content		
Unit	Description	Weightage* (%)
1.	Definition of a group, some examples of groups, some preliminary lemmas, subgroups, Lagrange's theorem, Euler's theorem, Fermat's theorem, counting principle, the condition for HK to be a subgroup, order of HK, normal subgroups, and quotient groups, characterizations of normal subgroups, homomorphism, isomorphism, first isomorphism theorem, simple group, Cauchy's theorem for abelian groups, relation of two homomorphic groups.	25
2.	Automorphism, inner automorphism, Cayley's theorem and its applications, permutation groups, permutation as a product of disjoint cycles and transpositions, even and odd permutations, alternating group, another counting principle, conjugate classes, class equation and its applications, Cauchy's theorem (general case), number of conjugate classes in permutation group.	25
3.	Sylow's theorem, first proof, definition of p-Sylow subgroup, second proof of Sylow's theorem, double cosets and its order, existence of p-Sylow subgroup in subgroups, second part of Sylow's theorem, number of p-Sylow subgroups in a group, third part of Sylow's theorem, examples based on Sylow's theorems.	25
4.	Direct products, external direct product and internal direct product, properties of internal direct product, finite abelian groups as direct product of cyclic groups, invariants of an abelian group of order power of prime p, the subgroup $G(s)$ of an abelian group G, for an integer s for a prime p, uniqueness of invariants, number of non-isomorphic abelian groups of a given order.	25

Teaching-Learning Methodology	Classroom teaching, problem solving, independent reading

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: Having completed this course, the learner will be able to	
1.	gain better understanding of permutation groups and their applications.
2.	express a given finite abelian group as the direct product of cyclic groups and, given two direct products of cyclic groups, determine whether or not they are isomorphic.
3.	solve problems using class equation and Sylow's theorems.

Suggested References:	
Sr. No.	References
1.	Herstein, I. N., Topics in Algebra, (Second Edition), Wiley Eastern Ltd., New Delhi, 1975.
2.	Fraleigh J. B., A First Course in Abstract Algebra (Third Edition), Narosa, 1983.
3.	Gallian J. A., Contemporary Abstract Algebra (Fourth Edition), Narosa, 2008.

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (IV)

Course Code	PS04EMTH58	Title of the Course	Mathematical Probability Theory
This course is same as PS03EMTH59 and can be offered to the students who have not taken the course PS03EMTH59.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	Students will learn types of convergence of a sequence of random variables which might be useful in the study of random phenomena arise in the real world.

Course Content		
Unit	Description	Weightage* (%)
1.	Random variables, Vector random variables, Limits of random variables, Probability measure, General probability space, Induced probability space, Distribution function of random variable, Jordan Decomposition theorem.	25
2.	Distribution function of vector random variables, Distribution function of dense subset of R, Expectation, Properties of expectation, Expectation of complex random variables, C_r- Inequality, Holder's Inequality, Minkowski Inequality, Jensen's Inequality, Chebyshev's Inequality.	25
3.	Monotone convergence theorem, Fatou's theorem, Dominated convergence theorem, Convergence in probability, Weak law of large numbers, Convergence almost surely, Toeplitz lemma, Cronecker lemma,, Kolmogorov's Inequality, Strong law of large numbers (iid case), Convergence in distribution, Convergence in r^{th} mean.	25
4.	Characteristic function, Properties of characteristic function, Inversion formula, Helly's first and second theorems, Helly-Bray theorem, Levy's theorem (continuity theorem, Central limit theorem (Lindeberg-Levy's theorem) (iid case).	25

Teaching-Learning Methodology	Classroom teachimg.

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: Having completed this course, the learner will be able to	
1.	learn stochastic processes used in the mathematical models to study real world problems.
2.	construct mathematical models.

Suggested References:	
Sr. No.	References
1.	B. R. Bhat, Modern Probability Theory: An Introductory Textbook, New Age International Publishers, 4th edition, 2014.
2.	A. K. Basu, Measure Theory and Probability, Prentice Hall of India, 2nd edition, 2015.
3.	Robert B. Ash, Probability and Measure Theory, Academic press, 2nd edition, 1999.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH59	Title of the Course	Number Theory and Cryptography
This course is same as PS03EMTH55 and can be offered to the students who have not taken the course PS03EMTH55.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. To enable students to learn the fundamental concepts of cryptography. 2. To understand the number theoretic foundations of modern cryptography and the principles behind their security. 3. To introduce advanced mathematical concept of elliptic curves and its applications in the Elliptic Curve Cryptography (ECC).

Course Content		
Unit	Description	Weightage* (%)
1.	Number Theory and Discrete Logarithm Problem: Simple substitution ciphers (except cryptanalysis), divisibility and GCD, modular arithmetic, prime numbers, unique factorization and finite fields, primitive roots in finite fields. The discrete logarithm problem.	25
2.	DLP based cryptosystems: The Diffie-Hellman key exchange, the ElGamal public key cryptosystem, difficulty of discrete log problem (DLP), a collision algorithm for the DLP, the Chinese remainder theorem, the Pohlig-Hellman algorithm.	25
3.	The RSA Algorithm: Euler's formula and roots modulo pq, the RSA public key cryptosystem, implementation and security issues, primality testing, Pollard's p-1 factorization algorithm.	25
4.	Elliptic curve cryptography: Elliptic curves, elliptic curve over finite fields, the elliptic curve discrete logarithm problem, elliptic curve cryptography.	25

Teaching-Learning Methodology	Classroom teaching, problem solving, independent reading

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: Having completed this course, the learner will be able to	
1.	appreciate the application of number theory in cryptography.
2.	have a basic understanding of some cryptosystems, algorithms, their security protocols and various attacks on them.
3.	view the subject as a combination of algebra, number theory, geometry through the study of elliptic curves and elliptic curve cryptography.
4.	understand applications of Mathematics in data security.

Suggested References:	
Sr. No.	References
1.	Hoffstein J., Pipher J., Silverman J. H., An Introduction to Mathematical Cryptography, Undergraduate Texts in Mathematics, Springer, New York, (2008).
2.	Douglas R. Stinson, Cryptograph: Theory and Practice, Second Edition, Chapman and Hall/CRC, (2005).
3.	N. Koblitz, A Course in Number Theory and Cryptography, Springer (1994).
4.	J. A. Buchmann, Introduction to Cryptography, Second Edition, Undergraduate Texts in Mathematics, Springer-Verlag, New York, (2004).

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (IV)

Course Code	PS04EMTH60	Title of the Course	Problems and Exercises in Mathematics II
This course is same as PS03EMTH57 and can be offered to the students who have not taken the course PS03EMTH57.			
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. Students will obtain a better understanding of the techniques of solving problems and exercises of group theory, ring theory, complex analysis, ODE and PDE. 2. Students will enhance the logical thinking, reasoning and problem-solving capability in group theory, ring theory, complex analysis, ODE and PDE.

Course Content		
Unit	Description	Weightage* (%)
1.	Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems.	25
2.	Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain, Polynomial rings and irreducibility criteria, Fields, finite fields, field extensions, Galois Theory.	25
3.	Algebra of complex numbers, polynomials, power series, trigonometric and hyperbolic functions, analytic functions, Cauchy-Riemann equations, Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, Maximum modulus principle, Taylor series, Laurent series, calculus of residues, conformal mappings, Mobius transformations.	25
4.	Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations (ODE), system of first order ODE, Lagrange and Charpit's method for solving first order partial	25

	differential equations (PDE), Classification of second order PDE.	

Teaching-Learning Methodology	Classroom teaching, independent thinking, problem solving

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: Having completed this course, the learner will be able to	
1.	gain a problem-solving perspective in the subjects like group theory, ring theory, complex analysis, ODE and PDE.
2.	solve problems efficiently asked in various competitive exams in mathematics.

Suggested References:	
Sr. No.	References
1.	Gallian, J., Contemporary Abstract Algebra, (Eight Edition), Books/Cole Cengage Learning, Belmont, 2013.
2.	Dummit, D.S. and Foote, R.M., Abstract Algebra, (Third Edition), John Wiley & Sons Inc., 2004.
3.	Simmons G. F., Differential Equations with Applications and Historical Notes, (Second Edition), McGraw-Hill International Editions, 1991.

4.	Raisinghania M. D., Advanced Differential Equations, (Sixth Revised Edition), S. Chand, 2013.
5.	Churchil, R.V., Brown, J. and Verle, R., Complex Variables and Applications, McGraw-Hill Publ. Co., Eighth edition, 2009.
6.	Conway J.B., Functions of One Complex Variable, (Second Edition), Narosa Publ. House, New Delhi, 1994.
7.	Bak Joseph and Newman Donald J., Complex Analysis. Third edition. Undergraduate Texts in Mathematics, Springer, New York, 2010.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH61	Title of the Course	Operator Theory
Total Credits of the Course	04	Hours per Week	04 hours

Course Objectives:	1. To introduce one of the most important branches of pure mathematics. 2. To link this theory with differential equations.

Course Content		
Unit	Description	Weightage* (%)
1.	Review of Hilbert space H, Orthogonal complement in H, Dual of H, Bounded operator, Existence of adjoint operator and its properties, Self-adjoint operator and its properties, Unitary operator and its properties, Fuglede-Putnam-Rosenblum theorem (i.e., Commutativity Theorem).	25
2.	Resolution of the identity E, the algebra $L^{\infty}(E)$, identifying $L^{\infty}(E)$ with a closed subalgebra of BL(H), Spectral theorem and its applications, Spectral decomposition.	25
3.	Symbolic calculus for normal operators and its applications on normal operators, Invariant subspace problem, Eigenvalue of normal operators, Positive operators and square roots, Polar decomposition and its uniqueness, Unitarily equivalent operators.	25
4.	Hilbert-Schmidt operators and their properties, Multiplier operator T_f on the sequence space l^2, Classification of the operator T_f in terms of f, Trace class operators, Hilbert-Schmidt and trace class norm, Relations between these two types of operators.	25

Teaching-Learning Methodology	Classroom teaching, Presentation by students, Supply of information about online resources

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 Quizzes, Assignments, and Attendance (As per CBCS R.6.8.3)	15%
3.	University Examination	70%

Course Outcomes: Having completed this course, the learner will be able to	
1.	realize the power of operator theory.
2.	apply this theory in Quantum Mechanics and other branches of Physics.

Suggested References:

Sr. No.	References
1.	Rudin W., Functional Analysis, Tata McGraw Hill Pub. Company, New Delhi, 1973.
2.	Conway J. B., A Course in Operator Theory, Graduate Studies in Mathematics, Volume 21, American Mathematical Society, Rhode Island, 2000.
3.	Limaye B. V., Functional analysis, 2nd Edition, New Age International Limited, New Delhi, 1996.

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (IV)

Course Code	PS04EMTH62	Title of the Course	Problems and Exercises in Mathematics III
Total Credits of the Course	04	Hours per Week	04

Course Objectives:	1. Students will obtain a better understanding of the techniques of solving problems and exercises of analysis, topology and number theory. 2. Students will enhance the logical thinking, reasoning and problem-solving capability analysis, topology and number theory.

Course Content		
Unit	Description	Weightage* (%)
1.	Riemann sums and Riemann integral, Improper Integrals, functions of bounded variation, Lebesgue measure, measurable functions, Lebesgue integral.	25
2.	Riemann-Stieltjes integral over rectifiable curves, Cauchy's integral formula for derivatives, Schwarz's lemma, Open mapping theorem, Rouche's theorem, Counting zero principle, Argument principle, space of analytic functions.	25
3.	Topology, basis, subbasis, dense sets, subspace and product topology separation axioms, connectedness, path-connectedness, compactness	25
4.	Fundamental theorem of arithmetic, divisibility in the set of integers, congruences, Chinese Remainder Theorem, Euler's totient-function, primitive roots, number of divisors, sum of divisors.	25

Teaching-Learning Methodology	Classroom teaching, independent thinking, problem solving

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: Having completed this course, the learner will be able to	
1.	gain a problem-solving perspective in the subjects like analysis, topology and number theory.
2.	solve problems efficiently asked in various competitive exams in mathematics.

Suggested References:	
Sr. No.	References
1.	H.L.Royden, Real Analysis (Third Edition) Mc. Millan, 1998.
2.	Rudin W., Principles of Mathematical Analysis (Third Edition), Tata MacGraw-Hill Publ., New Delhi, 1983.
3.	Churchil, R.V., Brown, J. and Verle, R., Complex Variables and Applications, McGraw-Hill Publ. Co., Eighth edition, 2009.
4.	Conway J.B., Functions of One Complex Variable, (Second Edition), Narosa Publ. House, New Delhi, 1994.
5.	Bak Joseph and Newman Donald J., Complex Analysis. Third edition. Undergraduate Texts in Mathematics, Springer, New York, 2010.
6.	Munkres, J., Topology: A First Course, (Second Edition), Prentice Hall of India Pvt. Ltd. New Delhi, 2003.
7.	Burton David M., Elementary Number Theory, (Seventh Edition) McGraw Hill Education, 2012.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH63	Title of the Course	Theory of Special Relativity
This course is same as PS03EMTH58 and can be offered to the students who have not taken the course PS03EMTH58.			
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. The course is aimed at giving exposure to special relativity. 2. Learning application of advanced tools of non-Euclidean geometry. 3. Application of Mathematics to special relativity and electromagnetic theory. 4. Introduction to relativistic approach to electrodynamics

Course Content		
Unit	Description	Weightage* (%)
1.	Historical background, Galilean transformations, non-invariance of Maxwell’s equations under Galilean transformation, postulates of special relativity, relativity of simultaneity, Michelson Morley experiment, Special Lorentz transformation, consequences of special Lorentz transformation, relativistic addition of velocities, General Lorentz transformation.	25
2.	Aberration of light (Newtonian and Relativistic), Doppler effect (Newtonian and Relativistic), space-time interval four dimensional formulation, Poincare structure of spacetime, Minkowski structure of spacetime.	25
3.	Covariance four dimensional form, principle of covariance, proper time, four dimensional vectors (Displacement, velocity) , mass of moving particle, covariant form of Newtonian’s laws, momentum 4-vector, relativistic kinetic energy, equivalence of mass and energy.	25
4.	Electric field, electrostatic potential, work and energy in electrostatics, magnetostatics, Lorentz force law and Biot-Savrat law, magnetic field and magnetostatic potential, Maxwell’s equations for electrodynamics, potential formulation in electrodynamics, relativistic electrodynamics (Maxwell’s equations and potentials).	25

Teaching-	Classroom teaching, Presentation by students, Use of ICT whenever

Learning Methodology	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: Having completed this course, the learner will be able to	
1.	have understanding of role of mathematics to theories in other branches of science.
2.	use the basic knowledge of special relativity to relevant situations.
3.	use the phenomena of optics in the framework of relativity.
4.	have understanding of non-Euclidean geometry and will be able to apply it further to general relativity.

Suggested References:	
Sr. No.	References
1.	Resnick, R, Introduction to Special Relativity, Wiley (Student Edition), 2007.
2.	Griffiths D.J., Introduction to Electrodynamics, , Cambridge University Press (4th Edition , South Asia Edition), 2020.
3.	Banerji, S. and Banerjee, A., The Special Theory of Relativity, Prentice-Hall of India, Delhi, 2012.
4.	Schutz, B.F., A First Course in General Relativity, Cambridge University Press (2nd Edition), 2009.
5.	Krori K.D., Fundamentals of Special and General Relativity, Prentice-Hall of India, Delhi, 2010.

On-line resources:

1. NPTEL Course: https://www.youtube.com/watch?v=0nHovWsWZTw&list=PLRuWd0sgheSZLMfA9yl_-cYEW_QyRlssD
   (Search Key on YouTube: Special Relativity + NPTEL)
2. Khan Academy Series: https://www.youtube.com/watch?v=iAPYsOaq-VY&list=PLqwfRVlgGdFA9KZBxFNifmVG2l5FSdBJm
   (Search Key on YouTube: Special Relativity + Khan Academy)

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH64	Title of the Course	Special Functions-I
This course is same as the course PS03EMTH60. The students opting for this course shall not be offered PS03EMTH60.			
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	In this course, preliminary of the Special Functions will be covered which lead to the study of certain Special Functions.

Course Content		
Unit	Description	Weightage* (%)
1.	Infinite products: definition, convergence, its association with series, absolute and uniform convergence. The Gamma and Beta functions: Weierstrass definition, Euler product formula, The difference equation $\Gamma(z+1) = z\,\Gamma(z)$, Series for $\Gamma'(z)/\Gamma(z)$; Beta function, the value of $\Gamma(z)\,\Gamma(1-z)$, Factorial function, Legendre duplication formula.	25
2.	Hypergeometric function ${}_2F_1[z]$: its convergence, Integral representation, Differential equation, Analyticity, ${}_2F_1[z]$ and its properties, Contiguous functions relations, Simple and quadratic transformations, Kummer's theorem for ${}_2F_1[-1]$.	25
3.	Generalized hypergeometric function ${}_pF_q[z]$: its convergence, Integral representation, Differential equation, Saalschütz's theorem, Whipple's theorem, Dixon's theorem.	25
4.	The Bessel function $J_n(z)$ as ${}_0F_1[z]$, Recurrence relations, Differential equation, A pure recurrence relation, A generating function, index half an odd integer, Bessel's integral, Modified Bessel function.	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: Having completed this course, the learner will be able to	
1.	understand the core concepts of infinite products, gamma and beta functions.
2.	derive the properties of special functions along with their existence and form an alternate representation of them.
3.	describe and analyse the generalized Hypergeometric function and the Bessel functions along with their properties in a researched based problem.
4.	transform a hypergeometric function to another hypergeometric function.

Suggested References:

Sr. No.	References
1.	Rainville, E. D., Special Functions, Macmillan Co., New York, 1960.
2.	Andrews, G. E., Askey, R. and Ranjan Roy, Special Functions, Cambridge University Press, 1999.
3.	Slater, L. J., Generalized Hypergeometric Functions, Cambridge University Press, Cambridge, NY, 1966.
4.	Wang, Z. X. and Guo, D. R., Special Functions, World Scientific Publ., Singapore, 1989.
5.	Andrews, L. C., Special Functions of Mathematics for Engineers, McGraw Hill Book Co, 1998.
6.	Watson, G. N., A treatise on the theory of Bessel functions, Cambridge University Press, Cambridge, UK, 1996.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH65	Title of the Course	Special Functions-II
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	After studying this course, students would be able to investigate and analyse the various special polynomials together with the concept of orthogonality and generating functions and finally apply them to understand more mathematics.

Course Content		
Unit	Description	Weightage* (%)
1.	Simple sets of polynomials, Orthogonality, An equivalent condition for orthogonality, Zeros of orthogonal polynomials, The three-term recurrence relation, The Christoffel-Darboux formula. Generating functions of the form $G(2xt - t^2)$, Sets generated by $e^t \psi(xt)$, The generating functions $A(t)\, exp[-xt(1 - t)]$.	25
2.	Confluent hypergeometric function ${}_1F_1[z]$ and its properties, Contiguous functions relations, Kummer's first and second formulas. Laguerre polynomial: Generating functions, Recurrence relations, Differential equation, Rodrigue's formula for Laguerre polynomial, Orthogonality, expansion of x^n in terms of Laguerre polynomial.	25
3.	Hermite polynomial: Generating functions, Recurrence relations, Differential equation, Rodrigue's formula for Hermite polynomial, Orthogonality, expansion of x^n in terms of Hermite polynomial. Legendre polynomial: Generating functions, Recurrence relations, Differential equation, Rodrigue's formula for Legendre polynomial, Orthogonality, expansion of x^n in terms of Legendre polynomial; Laplace first integral, Bounds.	25
4.	Jacobi polynomial: Explicit forms, Generating functions, Recurrence relations, Differential equation, Rodrigue's formula for Jacobi polynomial, Orthogonality. Chebyshev polynomials and Gegenbauer polynomial as the special cases of Jacobi polynomial.	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: Having completed this course, the learner will be able to	
1.	understand and apply the core concepts of orthogonality and generating functions.
2.	derive the various properties like differential equation, recurrence relations, orthogonality, etc. of different polynomials like Laguerre, Hermite and Legendre polynomials which has a vast application in physics.
3.	describe and analyze the confluent hypergeometric function and important polynomials along with their properties in a researched based problem.
4.	apply properties of the Jacobi polynomials to blend Chebyshev and Gegenbauer polynomials via the Jacobi polynomial.

Suggested References:	
Sr. No.	References
1.	Rainville, E. D., Special Functions, Macmillan Co., New York, 1960.
2.	Andrews, G. E., Askey, R. and Ranjan Roy, Special Functions, Cambridge University Press, 1999.
3.	Slater, L. J., Generalized Hypergeometric Functions, Cambridge University Press, Cambridge, NY, 1966.
4.	Wang, Z. X. and Guo, D. R., Special Functions, World Scientific Publ., Singapore, 1989.

5.	Andrews, L. C., Special Functions of Mathematics for Engineers, McGraw Hill Book Co, 1998.
6.	Watson, G. N., A treatise on the theory of Bessel functions, Cambridge University Press, Cambridge, UK, 1996.

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

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(M.Sc.) (Mathematics)
(Master of Science) (Mathematics) Semester (IV)

Course Code	PS04EMTH66	Title of the Course	Approximation Theory
Total Credits of the Course	04	Hours per Week	04
This course is same as PS03EMTH61 and can be offered to the students who have not taken the course PS03EMTH61.			

Course Objectives:	1. Students will obtain a better understanding of approximating continuous functions using the various techniques. 2. Students will enhance the idea on density theorems using positive linear operators.

Course Content		
Unit	Description	Weightage* (%)
1.	**Basics of Approximation Theory:** Introduction, Function Spaces, Convex and Strictly Convex Norms, The best approximation, Existence and uniqueness of best approximation (Finite-dimensional subspaces, Strictly convex spaces), Examples of nonexistence, Density theorems etc. A brief Introduction to: Classical approximation, Abstract approximation, Constructive approximation etc.	25
2.	**Approximation by Algebraic and Trigonometric Polynomials:** Approximation by Algebraic Polynomials: Uniform Approximation by Algebraic Polynomials, the First Weierstrass Theorem, Degree of approximation, Lipschitz classes, Different types of modulus of continuity. Approximation by Trigonometric Polynomials: The second Weierstrass Theorem, the Chebyshev Polynomials, Pointwise convergence and uniform convergence, Estimates with Second Order Moduli, Absolute Optimal Constants.	25
3.	**Positive Linear Operators** Positive linear operators and functionals; Chebyshev conditions to choose test functions, the Bohman-Korovkin Theorem, Bernstein operators, Estimates for the Bernstein Operators, Bernstein inequality, Improved Estimates, Lupas and Phillips operators (Quantum and Post	25

	quantum analogue)	
4.	**Jackson's Theorems, Approximation by Rational Functions**: A brief Introduction to Interpolation (Lagrange interpolation formula, Error bounds for Lagrange interpolation, Peano kernel), Chebyshev points and interpolants, Chebyshev polynomials and series, Barycentric interpolation formula, The Inequalities of Markov and Bernstein. Direct Theorems, Inverse Theorems, Convergence for differentiable functions, Convergence for analytic functions, Approximation by Rational Functions, Nonlinear approximation (why rational functions?), Rational best approximation, Pade approximation.	25

Teaching-Learning Methodology	Classroom teaching, independent thinking, problem solving

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: Having completed this course, the learner will be able to	
1.	Gain techniques of approximating continuous functions using rational function, polynomials and sequence of positive linear operators.
2.	Clear concept of the existence and uniqueness of best approximation.
3.	Clear concept of the Uniform Approximation by Algebraic Polynomials, Approximation by Trigonometric Polynomials.
4.	Clear concept of how to deal with Jackson's Theorems and various method of approximation methods.

Suggested References:	
Sr. No.	References
1.	Fundamentals of Approximation Theory, Hrushikesh N. Mhaskar, Devidas V. Pai CRC Press, 2000
2.	N. L. Carothers, A Short Course on Approximation Theory, Department of Mathematics and Statistics, Bowling Green State University.
3.	Lloyd N. Trefethen, Approximation Theory and Approximation Practice, Society for Industrial and Applied Mathematics Philadelphia, PA, USA, 2012.
4.	M J D Powell, Approximation theory and methods, 1981 (CUP, reprinted 1988).
5.	R. DeVore, G.G. Lorentz, Constructive Approximation, Springer Verlag, 1993.
6.	E. W. Cheney, An Introduction to Approximation Theory, 2nd ed., New York: Chelsea, 1982
7.	Pyramid Algorithms, A Dynamic Programming Approach to Curves and Surfaces for Geometric Modeling, R Goldman, Elsevier-2002.
8.	P. P. Korovkin, Linear operators and approximation theory, Hindustan Publishing Corporation, Delhi, 1960.
9.	Radu Paltanea, Approximation Theory Using Positive Linear Operators, Birkhauser Springer2004.
10.	Intelligent Systems: Approximation by Artificial Neural Networks, George A. Anastassiou, Springer, 2011.
11	Intelligent Systems II: Complete Approximation by Neural Network Operators, George A. Anastassiou, Springer, 2016.

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

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(Master of Science) (Mathematics)
(M.Sc.) (Mathematics) Semester (IV)

Course Code	PS04EMTH67	Title of the Course	Mathematical Modelling
This course is same as the course PS03EMTH62 and can be offered to the students who have not taken the course PS03EMTH62.			
Total Credits of the Course	4	Hours per Week	4 hours

Course Objectives:	1. The course is aimed at giving exposure to Mathematical modelling. 2. Apply difference equations and differential equations in solving some real world problems.

Course Content		
Unit	Description	Weightage* (%)
1.	**Introduction to Mathematical Modelling** Motivation, Modelling process, Linear and Non-linear difference equations, Equilibrium and Stability, Linear and Non-linear difference models, Mathematical Modelling Through Ordinary Differential Equations of First Order, Linear and Non-linear Growth and Decay Models, Electrical circuits, Compartment Models, Other related models	25
2.	**Mathematical Modelling Using System of First Order Ordinary Differential Equations** Steady State Solutions, Linearization and Local Stability Analysis, Population Dynamics, Epidemics, Medicine, Economics, Arms Race, Battles, Other related models	25
3.	**Mathematical Modelling in Celestial Dynamics Through Second Order Ordinary Differential Equations** Two Body Central Force Problem, Differential Equation of Orbit, Modelling of Planetary Motions, Circular Motion of Satellites, Electrical Circuits, Other related models	25
4.	**Mathematical Modelling using Partial Differential Equations** Fluid Flow Through Porus Medium, Heat Flow Through a Small Thin Rod, Wave Equation, Vibrating String, Vibrating Membrane, Traffic Flow, Other related models	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: Having completed this course, the learner will be able to	
1.	Formulate mathematical models related to Population, Newton's law of cooling, Drug delivery problem, Arms race, Economic Model, etc. using difference equation and solve them.
2.	Using first order differential equation and system of first order ordinary differential equation make mathematical model of Linear and Non-linear Growth and Decay Models, Carbon Dating, Drug distribution in body, Electrical circuits, Compartment Models and solve them.
3.	Make some mathematical models using second order ordinary differential equation and solve them.
4.	Mathematical modelling using partial differential equation for Fluid flow through porus medium, Heat flow through a small thin rod, Wave equation, Vibrating String, Traffic flow.

Suggested References:	
Sr. No.	References
1.	S. Banerjee, Mathematical modelling, CRC Press, Taylor and Francis Group, 2014.
2.	J.N. Kapur, Mathematical modelling, New Age International Publication, Second Edition, 2021.
3.	M. Braun, C.S. Coleman and D.A. Drew, Differential equation modes, Springer, 1994.
4.	Z. Ahsan, Differential Equations and their applications, Third Edition, PHI, 2016.

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