SYLLABUS

FOR

SEM III & IV

Program: M. Sc.

Course: Mathematics

From

Academic year

2025-26

Board of studies in Mathematics

Undergraduate and Post graduate

	Name	Designation	Institute/Industry
Head of the Department			
1	Dr. Khagenrai Chauhan	Chairman	Sir. P. T. Sarvajanik College of Science (Autonomous), Surat.
All Faculty Members of the Department			
1	Dr. Janki Vashi	Adhyapak Sahayak	Sir. P. T. Sarvajanik College of Science (Autonomous), Surat.
2	Dr. Jaimikaben Surawala	Adhyapak Sahayak	Sir. P. T. Sarvajanik College of Science (Autonomous), Surat.
Two Subject expert from the Parent University are to be nominated by Academic Council			
1	Prof. Subhash Krishnan	Associate Professor	K.J. Somaiya College of Science and Commerce, Mumbai. (Autonomous)
2	Dr. Udayan Prajapati	Head & Associate Professor	St. Xavier's College, Ahmedabad. (Autonomous)
One subject expert is to be nominated by Vice-Chancellor form a panel of six recommended by the Autonomous College Principal			
1	Dr. Kaushal Patel	Associate Professor	Department of Mathematics, Veer Narmad South Gujarat University, Surat.
One representative from Industry/ Corporate Sector/ allied areas to be nominated by Principal			
1	Mr. Dharmesh Patel	Officer	Canara Bank, Surat.
One Alumnus to be nominated by Principal			
1	Dr. Chhaya Desai	Assistant Professor	Department of Mathematics, Dr. S. S. Gandhi Engineering College, Surat.
Experts from outside the Autonomous College, whenever special courses of studies are to be formulated, to be nominated by the Principal.			
1	Dr. Jatin Desai	Retd. Associate Professor	Sir. P. T. Sarvajanik College of Science (Autonomous), Surat.

ACKNOWLEDGEMENT

I express my heartfelt gratitude to our dynamic Principal, Dr. Pruthul R. Desai, for his invaluable guidance and unwavering support throughout the curriculum restructuring process.

I would also like to express my sincere appreciation to the esteemed members of the Board of Studies. Their constructive suggestions and valuable contributions.

Above all, I am profoundly thankful to my dedicated colleagues in the Department, who tirelessly worked on compiling the syllabus.

Dr. Khagenrai J. Chauhan
Chairperson,
Board of Studies in Mathematics.

PROGRAMME OUTCOMES:

PO-1: Master Degree Programme in Mathematics will meet the present day needs of academic and Research, Institutions and Industries.

PO-2: Students may acquire depth knowledge in Algebra, Analysis, Topology, Functional Analysis, Optimization Techniques and Graph Theory which will motivate the students to go for higher studies/research in Mathematics.

PO-3: Inculcate critical thinking to carry out scientific investigation objectively without being biased with preconceived notions.

PO-4: Prepare students for pursuing research or careers in mathematical sciences and applied fields.

PO-5: Equip the student with skills to analyse problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions thereof.

PROGRAMME SPECIFIC OUTCOMES:

PSO-1: Mastery of Fundamental Mathematical Concepts (Algebra, Analysis, Geometry).

PSO-2: Will gain the ability to understand and deal with abstract concepts.

PSO-3: Communicate mathematical concepts effectively.

PSO-4: Ability to think critically and creatively.

PSO-5: Analyse and model real world problems based on mathematical principles.

PSO-6: Ability to solve problems which are modelled.

PSO-7: Communicate the solutions in rigorous mathematical language.

PSO-8: Ability to progress independently and ethically.

Content

M. Sc. (Sem-III & IV) Mathematics

Sr. No	Semester	Course	Course Number	Course Code	Course title
1	III	Core Course-VII	CC-VII	MHMSC-S3P7-4CR25	Cryptography
2		Core Course-VIII	CC-VIII	MHMSC-S3P8-4CR25	Topology
3		Core Course-IX	CC-IX	MHMSC-S3P9-4CR25	Functional Analysis
4		Elective Course	EC-VIII	MHMSC-S3E8-4CR25	Integral Equation
			EC-IX	MHMSC-S3E9-4CR25	Operations Research
			EC-X	MHMSC-S3E10-4CR25	Boundary Value Problems
			EC-XI	MHMSC-S3E11-4CR25	Special Functions
5		Skill based elective Course	SEC-I	MHMSC-S3SEC1-2CR25	Difference Equations
			SEC-II	MHMSC-S3SEC2-2CR25	The Elements of Galois Theory
			SEC-III	MHMSC-S3SEC3-2CR25	Lie Algebras
			SEC-IV	MHMSC-S3SEC4-2CR25	Fuzzy Sets and Logic
			SEC-V	MHMSC-S3SEC5-2CR25	SWAYAM/MOOC etc.
6		Practical	PR-III	MHMSC-S3PR3-6CR25	Lab Course-III
1	IV	Dissertation/Project /Internship	CCD-I	MHMSC-S4D1-24CR25	Dissertation/Project/ Internship

M. Sc. (Mathematics) Syllabus

M. Sc. (Mathematics) Syllabus with effect from the Academic year 2024-25

Course	Course Title	Course Number	Credits	Hour	Module	Lectures per module (1 Hr)	Examination		
							Internal Marks	External Marks	Total Marks
SEMESTER III									
Core Courses									
I	Cryptography	CC-VII	4	60	4	15	30	70	100
II	Topology	CC-VIII	4	60	4	15	30	70	100
III	Functional Analysis	CC-IX	4	60	4	15	30	70	100
Elective Course									
IV	Integral Equations	EC-VIII	4	60	4	15	30	70	100
	Operations Research	EC-IX	4	60	4	15	30	70	100
	Boundary Value Problems	EC-X	4	60	4	15	30	70	100
	Special Functions	EC-XI	4	60	4	15	30	70	100
Skill Enhancement Course									
V	Difference Equations	SEC-I	2	30	2	15	20	30	50
	The Elements of Galois Theory	SEC-II	2	30	2	15	20	30	50
	Lie Algebras	SEC-III	2	30	2	15	20	30	50
	Fuzzy Sets and Logic	SEC-IV	2	30	2	15	20	30	50
	SWAYAM/MOOC etc.	SEC-V	-	-	-	-	-	-	-
Core Courses PRACTICAL									
VI	Lab Course-III (CC-VII, VIII, IX)	CCP-III	6	12	-	-	60	140	200
SEMESTER IV									
Dissertation/Project									
I	Dissertation/Project/Internship	CCD-I	24	-	-	-	-	-	650

Semester- III

M.Sc. (Mathematics) Semester-III

Core Course- VII (CC-VII)

COURSE TITLE: CRYPTOGRAPHY

COURSE CODE: MHMSC-S3P7-4CR25 [CREDITS – 04]

Course learning outcome		
At the end of the course students will be able to: 1. Understand fundamental concepts of cryptography. 2. Describe the difference among symmetric, asymmetric and public key Cryptography. 3. Define basic requirements of cryptography. 4. Apply concepts of Encryption & Decryption. 5. Describe the process for implementing cryptographic systems.		
Module 1	**Simple Cryptosystems**	**[15L]**
Learning Objective 1. Students will learn about the cryptography.		
Learning Outcomes: At the end of this module the learner will be able to 1. understand the basic principles of simple cryptosystem. 2. apply cryptanalysis techniques.		
1	Some Simple Cryptosystems: The Shift Cipher, Substitution Cipher, Affine Cipher, Vigenere Cipher, Hill Cipher, Permutation Cipher, Stream Cipher. Cryptanalysis of Affine Cipher, Cryptanalysis of Substitution Cipher, Cryptanalysis of Vigenere Cipher, Cryptanalysis of Hill Cipher.	**[15L]**
Module 2	**Cryptanalysis**	**[15L]**
Learning Objective 1. To learn about Linear Cryptanalysis techniques.		
Learning Outcomes: At the end of this module the learner will be able to 1. Implement basic encryption and decryption techniques in various scenarios.		
2	Linear Cryptanalysis, Differential Cryptanalysis, Basic Encryption and Decryption, Encryption Techniques, Characteristics of Good Encryption Systems, International Data Encryption Algorithm, Shannon's Theory: Elementary probability theory, perfect secrecy, Entropy, Properties of Entropy, Product cryptosystems.	**[15L]**
Module 3	**Public Key Cryptography**	**[15L]**
Learning Objective 1. Understand the concept and significance of public key cryptography.		
Learning Outcomes: At the end of this module the learner will be able to 1. apply various testing algorithm 2. calculate square roots modulo m for a given value. 3. apply finite arithmetic in cryptographic algorithm.		
3	Public Key Cryptography, The RSA Cryptosystem, Primality Testing, Square roots modulo m, Factoring Algorithms, Other attacks on RSA, Finite fields, Elliptic Curves.	**[15L]**
Module 4	**Secret Key Cryptography**	**[15L]**
Learning Objective 1. To get the knowledge about secret key cryptography.		
Learning Outcomes:		

At the end of this module the learner will be able to 1. implement secret key cryptographic techniques for secure data encryption and decryption.		
4	Secret Key Cryptography, Diffie-Hellman Key Pre-distribution, Key Distribution Patterns, Diffie-Hellman Key Agreement. Pseudo-random Number Generation, BBS generator, Probabilistic Encryption, Digital Signatures, One-time Signatures, Rabin and ElGamal Signatures Schemes, Digital Signature Standard (DSS).	[15L]

References:

1. Koblitz , N., A Course in Number Theory and Cryptography, 2/e, Springer-Verlag, 1994.
2. Stallings, W., Cryptography and Network Security, 5/e, Pearson, 2010.
3. Stinson, D. R., Cryptography: Theory and Practice, 4/e, CRC Press, 1995.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Understand fundamental concepts of cryptography.		X	X	X	X	X		
Describe the difference among symmetric, asymmetric and public key Cryptography.		X	X	X	X	X		
Define basic requirements of cryptography.		X		X	X	X		
Apply concepts of Encryption & Decryption.		X		X	X	X		
Describe the process for implementing cryptographic systems.		X	X	X	X	X		

Practical:

Practical-1	Implementing and Cryptanalyzing the Shift Cipher and Substitution Cipher
Practical-2	Implementing and Cryptanalyzing the Vigenère Cipher and Hill Cipher
Practical-3	Implementing and Cryptanalyzing Basic Encryption Systems
Practical-4	Shannon's Theory of Cryptography and Entropy in Cryptosystems
Practical-5	Implementing RSA Cryptosystem and Exploring Primality Testing
Practical-6	Exploring Elliptic Curve Cryptography (ECC) and RSA Attacks
Practical-7	Implementing Diffie-Hellman Key Agreement and Pseudo-random Number Generation
Practical-8	Implementing Digital Signature Schemes (Rabin, ElGamal, DSS)

M.Sc. (Mathematics) Semester-III

Core Course- VIII (CC-VIII)

COURSE TITLE: TOPOLOGY

COURSE CODE: MHMSC-S3P8-4CR25 [CREDITS – 04]

<table>
<tr><th colspan="3">Course learning outcome</th></tr>
<tr><td colspan="3">At the end of this course, Students will be able to
1. Give an introduction about the basic notion of a topological space and basis for a topology.
2. Familiarize the notion of closed set, closure of a set and limit point.
3. Analysis and interpret the concept of connectedness and compactness of a subset of a topological space.
4. Analysis and able to differentiate between first countability axiom and second countability axiom.
5. Gaining the knowledge to prove Urysohn metrization theorem and Tychonoff theorem.</td></tr>
<tr><td>Module 1</td><td>Metric Spaces</td><td>[15L]</td></tr>
<tr><td colspan="3">Learning Objective
1. Students will gain the knowledge on some of the basic concept in set theory and group theory, Euclidean space etc.</td></tr>
<tr><td colspan="3">Learning Outcomes:
At the end of this module the learner will be able to
1. Gain expertise in the basic concepts of metric space.
2. understand the concept of various theorems.</td></tr>
<tr><td>1.1</td><td>Metric Spaces: The Definition and some Examples – Open sets – Closed sets.</td><td>[5L]</td></tr>
<tr><td>1.2</td><td>Convergence, Completeness and Baire's theorem: Cantor's Intersection Theorem, Baire's Theorem.</td><td>[3L]</td></tr>
<tr><td>1.3</td><td>Continuous mappings – Spaces of continuous functions – Euclidean Space, Unitary Space, Cauchy's Inequality, Minkowski's Inequality.</td><td>[7L]</td></tr>
<tr><td>Module 2</td><td>Topological Spaces</td><td>[15L]</td></tr>
<tr><td colspan="3">Learning Objective
1. To understand the weak topologies.</td></tr>
<tr><td colspan="3">Learning Outcomes:
At the end of this module the learner will be able to
1. understand the concept of bases.
2. understand the concept of weak topologies.</td></tr>
<tr><td>2.1</td><td>The Definition and some Examples – elementary concepts – open bases and open subbases, Lindelöf's Theorem,</td><td>[7L]</td></tr>
<tr><td>2.2</td><td>Weak topologies – The function algebra $C(X,\mathbb{R})$ and $C(X,\mathbb{C})$.</td><td>[8L]</td></tr>
<tr><td>Module 3</td><td>Compact Spaces</td><td>[15L]</td></tr>
<tr><td colspan="3">Learning Objective
1. To provide the knowledge of compact spaces.</td></tr>
<tr><td colspan="3">Learning Outcomes:
At the end of this module the learner will be able to
1. Understand the concept of compact spaces.
2. apply the concept to prove theorems.</td></tr>
</table>

3.1	Compact Spaces – Open covering and Compact spaces, continuity and compactness, the Heine-Borel Theorem, Products of spaces, Tychnoff's Theorem and locally compact spaces, the Generalised Heine-Borel Theorem, compactness for metric spaces, Lebesgue's covering lemma, Ascoli's Theorem,	**[15L]**
Module 4	**Separation**	**[15L]**
Learning Objective 1. To make the students aware of separation.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the basic idea of separation. 2. Represent separation axiom and use them to prove the many properties.		
4.1	Separation: T_0, T_1, T_2-Spaces, Regular Spaces, Hausdorff Spaces, Completely Regular and Normal Spaces.	**[6L]**
4.2	Tychonoff lemma, Urysohn's Lemma, the Tietze Extension Theorem, Urysohn's Imbedding Lemma, The stone-čech Compactification.	**[9L]**

References:

1. Simmons George F., Introduction to Topology and Modern Analysis, 1/e (1963), McGraw Hill Education, Reprint 2017.
2. James R. Munkres, Topology, A First Course, 2/e, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
3. Stephen Willard, General Topology, Dover Publication, 2004.
4. Fred H. Croom, Principles of Topology, Dover publications, Reprint 2016.
5. J. Dugundgi, Toplogy, 12/e, Allyn and Bacon, Boston, 1966.

Mapping of COs and PSOs

Course Learning Outcomes	**Programme Outcomes**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Give an introduction about the basic notion of a topological space and basis for a topology.	X	X	X				X	
Familiarize the notion of closed set, closure of a set and limit point.	X	X	X					
Analysis and interpret the concept of connectedness and compactness of a subset of a topological space.	X	X	X					
Analysis and able to differentiate between first countability axiom and second countability axiom.	X	X	X			X	X	
Gaining the knowledge to prove Urysohn metrization theorem and Tychonoff theorem.	X	X	X					

Practical:

Practical-1	Exploring Metric Spaces, Open and Closed Sets, Convergence, and Completeness
Practical-2	Continuous Mappings, Spaces of Continuous Functions, and Inequalities
Practical-3	Exploring Open Bases, Open Subbases, and Lindelöf's Theorem
Practical-4	Weak Topologies and Function Algebras $C(X, \mathbb{R})$ and $C(X, \mathbb{C})$
Practical-5	Compactness in Metric Spaces, Open Coverings, and the Heine-Borel Theorem
Practical-6	Products of Compact Spaces, Locally Compact Spaces, and Ascoli's Theorem
Practical-7	Separation Axioms (T_0, T_1, T_2-Spaces), Regular and Hausdorff Spaces
Practical-8	Urysohn's Lemma, Tychonoff Lemma, and the Tietze Extension Theorem

M.Sc. (Mathematics) Semester-III

Core Course-IX (CC-IX)

COURSE TITLE: FUNCTIONAL ANALYSIS

COURSE CODE: MHMSC-S3P9-4CR25 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Central concepts from functional analysis, including the Hahn-Banach theorem, the open mapping and closed graph theorems. 2. Banach-Steinhaus theorem, dual spaces, weak convergence, the Banach Analogue theorem, and the spectral theorem for compact self-adjoint operators. 3. The student is able to apply his or her knowledge of functional analysis to solve mathematical problems. 4. Appreciate the role of Inner product space. Understand and apply ideas from the theory of Hilbert spaces to other areas. 5. Understand the fundamentals of spectral theory, and appreciate some of its power.		
Module 1	**Banach Space**	**[15L]**
Learning Objective 1. To give the knowledge of the normed and banach space.		
Learning Outcomes: At the end of this module the learner will be able to 1. understand the basics of normed and banach space. 2. understand the topological properties.		
1	Normed and Banach spaces: Definition and examples of normed and Banach spaces. Operators and Functionals, Convex sets, Convex Functionals, Topological properties of normed spaces. Geometric properties of normed spaces.	**[15L]**
Module 2	**Hilbert Space**	**[15L]**
Learning Objective 1. To acquire knowledge on some of the basic concepts Hilbert space.		
Learning Outcomes: At the end of this module the learner will be able to 1. apply the concepts of inner products to analyse the structure of Hilbert space. 2. explore the properties and types of operators in Hilbert space.		
2	Inner product and Hilbert spaces: Basic definitions and properties. Orthogonal complements and projection theorem Reflexivity, Operators in Hilbert spaces. Lax Miligram lemma, projection on convex sets.	**[15L]**
Module 3	**Fundamental Theorems**	**[15L]**
Learning Objective 1. To learn about fundamental theorems. 2. to learn about principle of uniform boundedness.		

Learning Outcomes: At the end of this module the learner will be able to 1. understand the basic concept and significance of fundamental theorems. 2. understand the open mapping and closed graph theorem.		
3	Introduction to fundamental theorem, Hahn Banach Theorem, Principle of Uniform boundedness, Open Mapping and Closed graph theorem.	**[15L]**
Module 4	**The Riemann-Stieltjes Integral**	**[15L]**
Learning Objective 1. To learn about fixed point theorems and their applications.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand Fixed point theorems and their applications.		
4	Fixed point theorems and their applications, Banach Contraction Fixed point theorem and its generalization, Schauder's Fixed Point Theorem. Application of Fixed Point theorem to Matrix equations, Differential equations, Integral equation.	**[15L]**

References:

1. Simmons George F., Introduction to Topology and Modern Analysis, 1/e (1963), McGraw Hill Education, Reprint 2017.
2. A. H. Siddiqui, Khalil Ahmad, P. Manchanda, Introduction to Functional Analysis with Application, 1/e, Anamaya Publishers, 2007.
3. G. Backmenn and Narici, Functional Analysis, 2/e, Dover Publications Inc., 2003.
4. P.K. Jain, O. P. Ahuja and Khalil Ahmed, Functional Analysis, 1/e, Wiley-Interscience, 1996.
5. E. Kreyszig, Introductory Functional Analysis with Applications, 1/e, John Wiley & Sons Inc., 1978, Reprint 2007.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Central concepts from functional analysis, including the Hahn-Banach theorem, the open mapping and closed graph theorems.	X	X	X				X	
Banach-Steinhaus theorem, dual spaces, weak convergence, the Banach Analogue theorem, and the spectral theorem for compact self-adjoint operators.	X	X	X				X	
The student is able to apply his or her knowledge of functional analysis to solve mathematical problems.	X	X	X	X			X	

Appreciate the role of Inner product space. Understand and apply ideas from the theory of Hilbert spaces to other areas.	X	X	X	X			X	
Understand the fundamentals of spectral theory, and appreciate some of its power.	X	X	X	X				

Practical:

Practical-1	Exploring Normed Spaces, Banach Spaces, and Operators
Practical-2	Convex Sets, Convex Functionals, and Geometric Properties of Normed Spaces
Practical-3	Inner Product Spaces, Orthogonal Complements, and Projection Theorem
Practical-4	Reflexivity, Lax-Milgram Lemma, and Projection on Convex Sets
Practical-5	Hahn-Banach Theorem and Principle of Uniform Boundedness
Practical-6	Open Mapping Theorem and Closed Graph Theorem
Practical-7	Banach Contraction Fixed Point Theorem and Its Generalization
Practical-8	Schauder's Fixed Point Theorem and Applications to Differential and Integral Equations

M.Sc. (Mathematics) Semester-III

Elective Course- VIII (EC-VIII)

COURSE TITLE: INTEGRAL EQUATIONS

COURSE CODE: MHMSC-S3E8-4CR25 [CREDITS – 04]

<table>
<tr><th colspan="3">Course learning outcome</th></tr>
<tr><td colspan="3">At the end of this course, Students will be able to
1. Understand the concept of integral equations to identify different constituents to classify them and to apply the eigen-system method for solving the Fredholm type with separable kernel.
2. Derive procedures to for iterative methods to solve integral equations of both Fredholm and Volterra types without restricting the kernel to be separable and proving specific theorems of Fredholm's theory.
3. Design methods for solving the integral equations with symmetric kernel as linear/bilinear expansions over an orthonormal system of functions and to prove various theorems to analyse these methods. Apply the knowledge to solve problems.
4. Learn the use of numerical method for finding an eigenvalue and the analytical methods to solve the singular integral equations from Cauchy-type to Hilbert-type, which involve Cauchy's principal value, closed/open contours and the Riemann-Hilbert problem.</td></tr>
<tr><td>Module 1</td><td>Introduction to Integral Equations</td><td>[15L]</td></tr>
<tr><td colspan="3">Learning Objective
1. Student will learn about Integral Equations and their classifications.
2. Student will learn about Fredholm theorem.</td></tr>
<tr><td colspan="3">Learning Outcomes:
At the end of this module the learner will be able to
1. classify integral equations.
2. Solve integral equations.</td></tr>
<tr><td>1</td><td>Definition of Integral Equations and their classifications. Eigen values and Eigen functions. Special kinds of Kernel, Convolution Integral. The inner or scalar product of two functions. Reduction to a system of algebraic equations. Fredholm alternative, Fredholm theorem, Fredholm alternative theorem, an approximate method.</td><td>[15L]</td></tr>
<tr><td>Module 2</td><td>Method of Successive Approximation for Fredholm Equation</td><td>[15L]</td></tr>
<tr><td colspan="3">Learning Objective
1. To learn method of successive approximation for integral equations of the second kind.</td></tr>
<tr><td colspan="3">Learning Outcomes:
At the end of this module the learner will be able to
1. solve integral equations of both Fredholm and Volterra types</td></tr>
<tr><td>2</td><td>Method of successive approximations, Iterative scheme for Fredholm and Volterrra Integral equations of the second kind. Conditions of uniform convergence and uniqueness of series solution. Some results about the resolvent Kernel. Application of iterative scheme to Volterra integral equations of the second kind. Classical Fredholm's theory, the method of solution of Fredholm equation, Fredholm's First theorem, Fredholm's second theorem, Fredhom's third theorem.</td><td>[15L]</td></tr>
</table>

Module 3	Symmetric Kernel	[15L]
Learning Objective 1. Students will understand design methods for solving the integral equations with symmetric kernel.		
Learning Outcomes: At the end of this module the learner will be able to 1. Apply the knowledge to solve problems.		
3	Symmetric Kernels, Complex Hilbert space. An orthonormal system of functions, Riesz-Fisher theorem, A complete two-Dimensional orthonormal set over the rectangle a Fundamental property of Eigenvalues and Eigen functions for symmetric Kernels. Expansion in eigen functions and Bilinear form. Hilbert-Schmidt theorem and some immediate consequences. Definite Kernels and Mercer's theorem. Solution of a symmetric Integral Equation. Approximation of a general -Kernel (not necessarily symmetric) by a separable Kernel. The operator method in the theory of integral equations.	**[15L]**
Module 4	**Singular Integral Equations**	**[15L]**
Learning Objective 1. earn the use of numerical method for finding an eigenvalue and the analytical methods to solve the singular integral equations.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve the singular integral equations from Cauchy-type to Hilbert-type, which involve Cauchy's principal value, closed/open contours and the Riemann-Hilbert problem.		
4	Rayleigh-Ritz method for finding the first eigenvalue. The Abel Integral Equation. Inversion formula for singular integral equation with Kernel of the type $h(s) - h(t)$, $0 < \alpha < 1$, Cauchy's principal value for integrals solution of the Cauchy-type singular integral equation, closed contour, unclosed contours and the Riemann-Hilbert problem. The Hilbert-Kernel, solution of the Hilbert-Type singular Integral equation.	**[15L]**

References:

1. Ram P. Kanwal, Linear Integral Equations, 2/e, Springer Science+Business Media, LLC, 2012.
2. S. G. Mikhlin, Linear Integral Equations (translated from Russian), Hindustan Book Agency, 1960.
3. Rainer Kress, Linear Integral Equations, 3/e, Springer, 2014.
4. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations: Methods and Applications, Springer, 2011.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Understand the concept of integral equations to identify different constituents to classify them and to apply the eigen-system method for solving the Fredholm type with separable kernel.								
Derive procedures to for iterative methods to solve integral equations of both Fredholm and Volterra types without restricting the kernel to be separable and proving specific theorems of Fredholm's theory.								
Design methods for solving the integral equations with symmetric kernel as linear/bilinear expansions over an orthonormal system of functions and to prove various theorems to analyse these methods. Apply the knowledge to solve problems.								
Learn the use of numerical method for finding an eigenvalue and the analytical methods to solve the singular integral equations from Cauchy-type to Hilbert-type, which involve Cauchy's principal value, closed/open contours and the Riemann-Hilbert problem.								

Practical:

Practical-1	Integral Equations, Eigenvalues and Eigenfunctions, and the Fredholm Alternative
Practical-2	Special Kernels, Convolution Integral, and Approximate Methods
Practical-3	Successive Approximations and Iterative Schemes for Fredholm and Volterra Integral Equations
Practical-4	Classical Fredholm's Theory, Theorem Applications, and Resolvent Kernel
Practical-5	Symmetric Kernels, Hilbert Space, and Eigenfunction Expansion
Practical-6	Mercer's Theorem, Definite Kernels, and Approximation of Non-Symmetric Kernels
Practical-7	Rayleigh-Ritz Method for Eigenvalue Calculation and Abel Integral Equation
Practical-8	Singular Integral Equations, Cauchy's Principal Value, and Hilbert-Type Integral Equations

M.Sc. (Mathematics) Semester-III

Elective Course- IX (EC- IX)

COURSE TITLE: OPERATIONS RESEARCH

COURSE CODE: MHMSC-S3E9-4CR25 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Apply decision theory approaches, decision tree analysis, and Bayesian analysis to make informed decisions under uncertainty and risk in various business environments. 2. Use PERT/CPM techniques to analyze project timelines, perform critical path analysis, and manage time-cost trade-offs and resource allocation in projects. 3. Develop and apply inventory control models and solve queueing problems using probabilistic distributions, improving inventory management and service efficiency in operations.		
Module 1	**Decision Theory**	**[15L]**
Learning Objective 1. Learn the steps involved in the decision theory approach, and how it is applied in various decision-making scenarios. 2. Study the different types of decision-making environments, including decision-making under uncertainty and risk, and understand the role of posterior probabilities in Bayesian analysis. 3. Learn how to use decision tree analysis for structured decision-making and apply the concept of utilities in decision-making under risk.		
Learning Outcomes: At the end of this module the learner will be able to 1. Explain the key steps in the decision theory approach and apply them to solve practical decision-making problems. 2. Distinguish between decision-making under uncertainty and decision-making under risk, and understand how Bayesian analysis is used to update probabilities. 3. Construct and analyze decision trees for optimal decision-making and apply utility theory to evaluate choices under risk.		
1	Steps in Decision Theory Approach - Types of Decision-Making Environments - Decision Making Under Uncertainty - Decision Making under Risk - Posterior Probabilities and Bayesian Analysis - Decision Tree Analysis - Decision Making with Utilities.	**[15L]**
Module 2	**Project Management: PERT and CPM**	**[15L]**
Learning Objective 1. Learn the basic differences between PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method), and how these techniques are used for project management. 2. Understand the components of PERT/CPM networks, including precedence relationships, and learn how to conduct critical path analysis to optimize project timelines. 3. Learn how to incorporate probability in PERT analysis, understand project time-cost trade-offs, and effectively allocate resources to improve project outcomes.		

Learning Outcomes:

At the end of this module the learner will be able to

1. Explain the key differences between PERT and CPM techniques and select the appropriate method based on project requirements.
2. Construct PERT/CPM networks, identify the critical path, and evaluate project timelines to ensure efficient project management.
3. Analyze time-cost trade-offs, update project schedules, and allocate resources effectively to optimize project outcomes.

2	Basic Differences between PERT and CPM - Steps in PERT/CPM Techniques - PERT/CPM Network Components and Precedence Relationships - Critical Path Analysis - Probability in PERT Analysis - Project time-cost Trade Off - Updating the Project - Resource Allocation.	**[15L]**
Module 3	**Deterministic Inventory Control Models**	**[15L]**

Learning Objective

1. Learn the meaning of inventory control, its functional classification, and the advantages of carrying inventory for business operations.
2. Understand the key features of deterministic inventory models with and without shortages, and learn about probabilistic inventory control models, including single-period models.
3. Learn to build and apply deterministic and probabilistic inventory models to make informed decisions regarding inventory management, including models with and without setup costs.

Learning Outcomes:

At the end of this module the learner will be able to

1. Explain the concept of inventory control, classify different inventory functions, and articulate the benefits of carrying inventory in business operations.
2. Apply deterministic inventory models with and without shortages, and analyze single-period probabilistic models, including those with setup costs.
3. Use inventory models to make decisions that optimize inventory levels, minimize costs, and address shortages or setup costs effectively.

3	Meaning of Inventory Control - Functional Classification - Advantage of Carrying Inventory - Features of Inventory System - Inventory Model building – Deterministic Inventory Models with no shortage - Deterministic Inventory with Shortages. Probabilistic Inventory Control Models: Single Period Probabilistic Models without Setup cost - Single Period Probabilities Model with Setup cost.	**[15L]**
Module 4	**Queueing Theory**	**[15L]**

Learning Objective

1. Learn how to use inventory models to determine the optimal inventory levels that minimize stockouts and overstocking.
2. Understand how to apply inventory models to minimize total inventory costs, including holding costs, ordering costs, and shortage costs.
3. Learn how to use inventory models to manage and minimize the impact of shortages and setup costs in the inventory management process.

Learning Outcomes: At the end of this module the learner will be able to 1. Apply inventory models to calculate the most efficient inventory levels and avoid unnecessary excess or shortage of stock. 2. Minimize the total costs related to inventory management by using models to balance ordering, holding, and shortage costs. 3. Make informed decisions that effectively address and reduce shortages and setup costs through appropriate inventory control strategies.		
4	Essential Features of Queueing System - Operating Characteristic of Queueing System - Probabilistic Distribution in Queueing Systems - Classification of Queueing Models (M/M/1, M/M/S) - Solution of Queueing Models - Probability Distribution of Arrivals and Departures - Erlangian Service times Distribution with k-Phases.	**[15L]**

References:

1. F.S. Hillier and J.Lieberman, Introduction to Operations Research, 8/e, Tata McGraw Hill Publishing Company, New Delhi, 2006.
2. Sharma S. D., Operations Research, 18/e, Kedar Nath Ram Nath Publications.
3. Sharma J. K., Operations Research Theory and Applications, 6/e, Trinity Press.
4. Hamdy A. Taha, Operations Research – An Introduction, 10/e, Pearson Education.
5. G. Hadley, Linear Programming, 2/e, Adition-Wesley Publishing Co. INC, 1963.

Mapping of COs and PSOs

Course Learning Outcomes	**Programme Outcomes**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Apply decision theory approaches, decision tree analysis, and Bayesian analysis to make informed decisions under uncertainty and risk in various business environments.	X	X	X	X	X	X	X	
Use PERT/CPM techniques to analyze project timelines, perform critical path analysis, and manage time-cost trade-offs and resource allocation in projects.	X	X	X	X	X	X	X	
Develop and apply inventory control models and solve queueing problems using probabilistic distributions, improving inventory management and service efficiency in operations.	X	X	X	X	X	X	X	

Practical:

Practical-1	Decision-Making Under Uncertainty and Risk
Practical-2	Posterior Probabilities and Bayesian Analysis
Practical-3	Critical Path Method (CPM) and Project Time-Cost Trade-Off
Practical-4	PERT Analysis and Resource Allocation
Practical-5	Deterministic Inventory Models with and without Shortages
Practical-6	Probabilistic Inventory Control Models
Practical-7	Basic Queueing Models (M/M/1, M/M/S) and their Solutions
Practical-8	Erlangian Service Times and Advanced Queueing Models

M.Sc. (Mathematics) Semester-III

Elective Course- X (EC-X)

COURSE TITLE: BOUNDARY VALUE PROBLEMS

COURSE CODE: MHMSC-S4E10-4CR25 [CREDITS – 04]

<table>
<tr><th colspan="3">Course learning outcome</th></tr>
<tr><td colspan="3">At the end of this course, Students will be able to
1. Solve Ordinary and Partial Differential Equations Using Green's Function.
2. Apply Integral Transform Methods to Solve Boundary Value Problems.
3. Analyze and Solve Hydrodynamics and Elasticity Problems.
4. Apply Perturbation Methods to Diffraction and Elasticity Theory.</td></tr>
<tr><th>Module 1</th><th>Applications to Ordinary Differential Equations</th><th>[15L]</th></tr>
<tr><td colspan="3">Learning Objective
1. Learn how to use Green's function to transform boundary value problems of self-adjoint differential equations with homogeneous boundary conditions into integral equations.
2. Study the applications of Green's function to solve ordinary differential equations, specifically for initial value problems and boundary value problems.
3. Understand the concept of modified Green's functions and apply them to N-order ordinary differential equations.</td></tr>
<tr><td colspan="3">Learning Outcomes:
At the end of this module the learner will be able to
1. Apply Green's function to reduce boundary value problems of self-adjoint differential equations to integral equation forms.
2. Use Green's function and Dirac delta functions to solve initial and boundary value problems effectively.
3. Apply modified Green's functions to solve higher-order ordinary differential equations and interpret the results.</td></tr>
<tr><td>1</td><td>Applications to Ordinary Differential Equations; Initial value problems, Boundary Value Problems. Dirac Delta functions. Green's function approach to reduce boundary value problems of a self-adjoint-differential equation with homogeneous boundary conditions to integral equation forms. Green's function for N -order ordinary differential equation. Modified Green's function.</td><td>[15L]</td></tr>
<tr><th>Module 2</th><th>Applications to partial differential equations</th><th>[15L]</th></tr>
<tr><td colspan="3">Learning Objective
1. Learn the integral representation formulas used to solve the Laplace and Poisson equations, including the Newtonian, single-layer, and double-layer potentials.
2. Study Green's function for Laplace's equation in free space and bounded regions, and understand its use in solving interior and exterior Dirichlet and Neumann problems.
3. Learn how to use Green's function and Poisson's integral formula to solve boundary value problems for Laplace's equation, including applications to spaces bounded by grounded plates or an infinite cylinder.</td></tr>
</table>

Learning Outcomes:

At the end of this module the learner will be able to

1. Apply integral representation formulas to solve the Laplace and Poisson equations using Newtonian, single-layer, and double-layer potentials.
2. Use Green's function to solve interior and exterior Dirichlet and Neumann problems for Laplace's equation in various geometries.
3. Use Poisson's integral formula and Green's function to solve boundary value problems in regions bounded by grounded two parallel plates or an infinite circular cylinder.

2	Applications to partial differential equations: Integral representation formulas for the solution of the Laplace and Poisson Equations. The Newtonian, single-layer and double-layer potentials, Interior and Exterior Dirichlet problems, Interior and Exterior Neumann problems. Green's function for Laplace's equation in a free space as well as in a space bounded by a ground vessel. Integral equation formulation of boundary value prolems for Laplace's equation. Poisson's Integral formula. Green's function for the space bounded by grounded two parallel plates or an infinite circular cylinder. The Helmholtz equation.	**[15L]**
Module 3	**Integral Transform Methods**	**[15L]**

Learning Objective

1. Learn the concepts of Fourier and Laplace transforms, as well as the convolution integral, and their applications in solving integral and differential equations.
2. Study the application of Fourier and Laplace transforms to Volterra integral equations with convolution-type kernels, and learn to solve them using these methods.
3. Explore the use of integral transforms to solve mixed boundary value problems, including two-part, three-part, and generalized three-part boundary value problems.

Learning Outcomes:

At the end of this module the learner will be able to

1. Apply Fourier and Laplace transforms effectively to solve integral and differential equations.
2. Solve Volterra integral equations with convolution-type kernels using integral transform methods.
3. Apply integral transform methods to solve various mixed boundary value problems, including two-part, three-part, and generalized three-part problems.

3	Integral Transform methods: Introduction, Fourier transform. Laplace transform. Convolution Integral. Application to Volterra Integral Equations with convolution-type Kernels. Hilbert transform. Applications to mixed Boundary Value Problems: Two-part Boundary Value problems, Three-part-Boundary Value Problems, Generalized Three-part Boundary Value problems.	**[15L]**
Module 4	**Integral equation perturbation methods**	**[15L]**

Learning Objective

1. Learn the basic procedure of perturbation methods for solving integral equations and their applications in various fields such as electrostatics and hydrodynamics.
2. Study how perturbation methods are applied to low-Reynolds-number hydrodynamics, including steady Stokes flow and its effects on boundary conditions and oscillations.
3. Understand the application of perturbation methods to elasticity problems such as torsion, rotation, crack problems, and diffraction theory.

Learning Outcomes:

At the end of this module the learner will be able to

1. Apply perturbation techniques to solve integral equations in practical applications like electrostatics and hydrodynamics.
2. Apply perturbation methods to analyze various types of Stokes flow problems, including steady, rotary, and oscillatory motions.
3. Use perturbation methods to solve elasticity problems involving rotation, torsion, crack analysis, and diffraction phenomena.

4	Integral equation perturbation methods: Basic procedure, Applications to Electrostatics, Low-Reynolds-Number Hydrodynamics: Steady stokes Flow, Boundary effects on Stokes flow, Longitudinal oscillations of solids in stokes Flow, Steady Rotary Stokes Flow, Rotary Oscillations in Stokes Flow, Rotary Oscillation in Stokes Flow, Oseen Flow-Translation Motion, Oseen Flow-Rotary motion Elasticity, Boundary effects, Rotation, Torsion and Rotary Oscillation problems in elasticity, crack problems in elasticity, Theory of Diffraction.	**[15L]**

References:

1. R. P. Kanwal: Linear Integral Equations–Theory and Technique; Academic Press, Inc.; 2014 edition.
2. S. G. Mikhlin: Linear Integral Equations; Dover Publications Inc.; 2020 edition.
3. Rainer Kress: Linear Integral Equations; Springer, 3/e.

Mapping of COs and PSOs

Course Learning Outcomes	**Programme Outcomes**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Solve Ordinary and Partial Differential Equations Using Green's Function.	X	X	X	X		X	X	
Apply Integral Transform Methods to Solve Boundary Value Problems.	X	X	X	X		X	X	
Analyze and Solve Hydrodynamics and Elasticity Problems.	X	X	X	X	X	X	X	
Apply Perturbation Methods to Diffraction and Elasticity Theory.	X	X	X	X	X	X	X	

Practical:

Practical-1	Solving Initial Value and Boundary Value Problems Using Green's Function
Practical-2	Green's Function for Higher-order ODEs and Modified Green's Function
Practical-3	Green's Function and Integral Representation for Laplace and Poisson Equations
Practical-4	Green's Function for Boundaries and Helmholtz Equation
Practical-5	Fourier and Laplace Transforms for Integral Equations
Practical-6	Application of Integral Transforms to Boundary Value Problems
Practical-7	Electrostatics and Low-Reynolds-Number Hydrodynamics Using Integral Equation Perturbation Methods
Practical-8	Elasticity and Diffraction Theory Using Integral Equation Perturbation Methods

M.Sc. (Mathematics) Semester-III

Elective Course- XI (EC-XI)

COURSE TITLE: SPECIAL FUNCTIONS

COURSE CODE: MHMSC-S3E11-4CR25 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Gain a comprehensive understanding of special functions such as Gamma, Beta, Hypergeometric, Bessel, and Legendre functions. 2. Learn to apply integral representations and transformations of these functions in various mathematical contexts. 3. Develop the ability to solve differential equations related to these special functions. 4. Explore the elementary properties, recurrence relations, and orthogonality of these functions. 5. Students will be able to give the rigorous proof of various theorems.		
Module 1	**The Gamma and Beta Function**	**[15L]**
Learning Objective 1. Learn the definition, properties, and applications of the Gamma and Beta functions, and their relationship to the factorial function. 2. Study and apply advanced mathematical results like the Gauss multiplication formula, Legendre's duplication formula, and Gauss multiplication theorem in solving integrals and functions. 3. Gain an understanding of special functions such as the incomplete gamma function, incomplete beta function, Mittag-Leffler's function, and the Riemann Zeta function, and learn how to apply them in various mathematical contexts.		
Learning Outcomes: At the end of this module the learner will be able to 1. Define the Gamma and Beta functions, apply them to solve problems, and understand their connection to factorials. 2. Use key theorems like the Gauss multiplication formula and Legendre's duplication formula to simplify and solve complex problems. 3. Analyze and apply special functions such as the incomplete gamma function, Mittag-Leffler's function, and Riemann Zeta function in various mathematical, physical, and engineering applications.		
1	Euler's integral for Gamma (Z), Gamma and Beta functions and its elementary properties Factorial function, Gauss Multiplication formula, Legendre's duplication formula, Gauss multiplication theorem, Incomplete gamma function, Incomplete beta function, Mittag-leffler's function, Riemann Zeta Function.	**[15L]**
Module 2	**The Hypergeometric Function**	**[15L]**
Learning Objective 1. Learn the definition of hypergeometric functions and their integral representation, along with fundamental properties and transformations. 2. Study Gauss's hypergeometric function, including its differential equation, solutions, and methods for evaluating the function.		

3. Understand generalized hypergeometric series, the function $_uF_v$, relations of contiguity, and Kummer's theorem, and explore bilateral hypergeometric series.		
Learning Outcomes: At the end of this module the learner will be able to 1. Define hypergeometric functions, represent them as integrals, and apply transformations in various mathematical contexts. 2. Solve Gauss's hypergeometric differential equation and evaluate hypergeometric functions. 3. Work with generalized hypergeometric series, use relations of contiguity, and apply Kummer's theorem in the evaluation and manipulation of hypergeometric functions.		
2	Definition, Integral representation of hypergeometric function, Transformations, Gauss's hypergeometric functions and its elementary properties, Gauss's hypergeometric differential equation and its solution, Gauss's hypergeometric function, Evaluation of hypergeometric function, relations of contiguity, theorem due to Kummer's, Generalized Hypergeometric series, the function of $_uF_v$, Bilateral hypergeometric series.	**[15L]**
Module 3	**Bessel functions**	**[15L]**
Learning Objective 1. Learn the formulation of Bessel's differential equation and its solutions, focusing on Bessel functions $J_u(x)$. 2. Study the recurrence relations, generating functions, and integral representations of Bessel functions, along with their orthogonality properties. 3. Understand the modified Bessel functions, their properties, and how they relate to the standard Bessel functions.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve Bessel's differential equation and apply the solution to various problems involving Bessel functions $J_u(x)$		
3	Bessel differential equation and its solution, Bessel's functions $J_u(x)$, recurrence relation, generating functions, integral representation, and orthogonality of Bessel functions, modified Bessel function and its properties.	**[15L]**
Module 4	**Legendre functions**	**[15L]**
Learning Objective 1. Learn the formulation of Legendre's differential equation and its solutions, focusing on Legendre functions P(x) and Q(x). 2. Study the relations between Legendre functions, including their multiplication properties, integral representations, and the associated Legendre functions. 3. Learn to compute and apply integrals that involve Legendre functions and their associated forms in various mathematical and physical problems.		
Learning Outcomes: At the end of this module the learner will be able to 1. Solve Legendre's differential equation and apply the solutions to problems involving Legendre functions P(x) and Q(x). 2. Use relationships between Legendre functions, including multiplication and integral representations, in solving problems. 3. Work with associated Legendre functions and solve integrals involving Legendre functions in both theoretical and applied contexts.		

4	Legendre's differential equation and its solution, Relations between Legendre functions, The function P(x) and Q(x), Multiplications of two Legendre functions, Integral representations, Integrals involving Legendre functions, Associated Legendre functions.	**[15L]**

References:

1. Rainville E.D.: Special Function, The Macmillan Company, New York, 1960.
2. Sharma J.N. and Gupta R.K.: Special Functions, Krishna's Educational Publishers.
3. Andrews G.E., Askey R., Roy R.: Special Function, Cambridge University Press, 1999.
4. Bell W.W.: Special Function for Scientists and Engineers, D. Van Nostrand Company Ltd., 1968.
5. Wang Z.X., Guo D.R.: Special Function, World Scientific, 2010.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Gain a comprehensive understanding of special functions such as Gamma, Beta, Hypergeometric, Bessel, and Legendre functions.	X	X	X			X	X	
Learn to apply integral representations and transformations of these functions in various mathematical contexts.	X	X	X					
Develop the ability to solve differential equations related to these special functions.	X	X	X	X		X	X	
Explore the elementary properties, recurrence relations, and orthogonality of these functions.	X	X	X	X		X	X	
Students will be able to give the rigorous proof of various theorems.	X	X	X					

Practical:

Practical-1	Euler's Integral for Gamma and Beta Functions
Practical-2	Incomplete Gamma Function, Mittag-Leffler's Function, and Riemann Zeta Function
Practical-3	Integral Representation and Properties of Gauss's Hypergeometric Function
Practical-4	Generalized Hypergeometric Series and Kummer's Theorem
Practical-5	Solving Bessel's Differential Equation and Investigating Bessel's Functions
Practical-6	Modified Bessel Function and Orthogonality of Bessel Functions
Practical-7	Solving Legendre's Differential Equation and Exploring Legendre Functions
Practical-8	Operations on Legendre Functions, Integral Representations, and Associated Legendre Functions

M.Sc. (Mathematics) Semester-III

Skill Based Elective Course (SEC-I)

COURSE TITLE: DIFFERENCE EQUATIONS

COURSE CODE: MHMSC-S3SEC1-2CR25 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. understand the basics of Difference Calculus. 2. understand the First order difference equation. 3. understand the Linear Difference equations. 4. understand the homogeneous and Inhomogeneous equations. 5. understand the system of Linear Difference equations.		
Module 1	**First and Second Order Difference Equations**	**[15L]**
Learning Objective 1. Students will gain the knowledge on first and second order difference equations. 2. Students will able to solve first and second order difference equations.		
Learning Outcomes: At the end of this module the learner will be able to 1. Gain expertise in the basic concepts of difference equations and able to solve difference equations.		
1.1	First order difference equations, introduction, notations and basic concepts, Difference calculus,	**[6L]**
1.2	Second order difference equations, The constant coefficient case (Homogeneous and Inhomogeneous equation), The variable coefficient case (Homogeneous and Inhomogeneous equation), Casoratian $W(n)$ of the solutions.	**[9L]**
Module 2	**Higher order linear difference equations and System of first order difference equations**	**[15L]**
Learning Objective 1. To understand the higher order linear difference equations and system of first order difference equations.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve higher order linear difference equations. 2. solve systems of first order difference equations.		
2.1	Higher order linear difference equations.	**[4L]**
2.2	Systems of first order difference equations, Second order difference equation as a system, Further results on matrix powers	**[11L]**

References:

1. Saber N. Elaydi, An Introduction to Difference Equations, 3/e, Springer, 2004.
2. Samual Golberg, Introduction to Difference Equations, John Wiley & Sons, Inc., 1958.
3. Stephen H. Friedberg, Arnold J. Insel, and Lawrence E. Spence, Elementary Linear Algebra, International Edition, 2/e, Pearson Higher Education.

4. H. Levy and F. Lessman, Finite Difference Equations, 1/e, Dover Publications, 2011.
5. Murray R. Spiegel, Calculus Of Finite Differences And Difference Equations, 1/e, McGraw Hill, 2020.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
understand the basics of Difference Calculus.	X	X	X					
understand the First order difference equation.	X	X	X			X		
understand the Linear Difference equations.	X	X	X			X		
understand the homogeneous and Inhomogeneous equations.	X	X	X			X	X	
understand the system of Linear Difference equations.	X	X	X			X	X	

M.Sc. (Mathematics) Semester-III

Skill based Elective Course (SEC-II)

COURSE TITLE: THE ELEMENTS OF GALOIS THEORY

COURSE CODE: MHMSC-S3SEC2-2CR25 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. To study Some important types of extensions. 2. To study Galois Theory.		
Module 1	**The Elements of Field Theory**	**[15L]**
Learning Objective 1. Students will gain the knowledge on important types of extensions.		
Learning Outcomes: At the end of this module the learner will be able to 1. learn about structure of algebraic extensions. 2. understand the necessary facts from theory of groups.		
1	Some important types of extensions, The minimal polynomial, The structure of simple algebraic extensions, The algebraic nature of finite extensions, The structure of composite algebraic extensions, Composite finite extensions, The theorem that a composite algebraic extension is simple, The field of algebraic numbers, The composition of fields, Necessary facts from theory of groups, definition, Subgroup, Normal divisors, factor groups, Homomorphic mappings.	**[15L]**
Module 2	**Galois Theory**	**[15L]**
Learning Objective 1. To gain the knowledge of Galois theory.		
Learning Outcomes: At the end of this module the learner will be able to 1. gain the knowledge of Galois group. 2. gain the knowledge of a theorem about conjugate elements.		
2	Galois Theory, Normal extensions, Automorphisms of fields, The Galois group, The order of the Galois group, The Galois correspondence, A theorem about conjugate elements, The Galois group of a normal subfield, The Galois group of the composition of two fields.	**[15L]**

References:

1. M. M. Postnikov (Translated by Ann Swinfen), Foundations of Galois Theory, 1/e, Dover Publications, Inc., 2004.
2. D. J. H. Garling, A Course in Galois Theory, 1/e, Cambridge University Press, 1986.
3. David A. Cox, Galois Theory, 2/e, John Wiley & Sons, Inc., 2012.
4. Jorg Bewersdorff (Translated by David Kramer), Galois theory for beginners: A historical perspective, 1/e, American Mathematical Society, 2006.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
To study Some important types of extensions.	X	X		X		X		
To study Galois Theory.	X	X		X		X		

M.Sc. (Mathematics) Semester-III

Skill based Elective Course (SEC-III)

COURSE TITLE: LIE ALGEBRA

COURSE CODE: MHMSC-S3SEC3-2CR25 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. To introduce the structure and classification of Lie algebras. 2. To explore representations and substructures of Lie algebras. 3. To understand theorems on Simple and Semi simple Lie algebras and their applications. 4. To familiarize nilpotent and solvable Lie algebras and prove the Engel's theorem. 5. To derive various decomposition theorems on Lie algebras. 6. To understand the classification of Lie algebras through Dynkin diagrams. 7. To understand the applications of Lie algebras in Mathematics and Theoretical Physics.		
Module 1	**Fundamentals of Lie Algebras**	**[15L]**
Learning Objective 1. To introduce the structure and classification of Lie algebras. 2. To explore representations and substructures of Lie algebras. 3. To understand theorems on Simple and Semi simple Lie algebras and their applications. 4. To familiarize nilpotent and solvable Lie algebras and prove the Engel's theorem and Lie's Theorem.		
Learning Outcomes: At the end of this module the learner will be able to 1. To understand the concept of Lie algebra. 2. To know the substructures and operations on Lie algebra. 3. To study theorem based on Simple and Semi simple Lie algebras and their applications. 4. To learn nilpotent and solvable Lie algebras and prove the Engel's theorem and Lie's Theorem.		
1.1	**Introduction to Lie Algebras:** Definition and examples, Lie bracket (commutator), antisymmetric, Jacobi identity, **Subalgebras and Ideals:** Subalgebras, ideals, quotient Lie algebras, Simple and semi simple Lie algebras, **Homomorphisms and Isomorphisms:** Lie algebra homomorphisms and their kernels and images, Isomorphisms and automorphisms, **Derived Series and Lower Central Series:** Solvable and nilpotent Lie algebras, Engel's Theorem and Lie's Theorem (Statements and applications)	**[15L]**
Module 2	**Applications of Lie Algebras**	**[15L]**
Learning Objective 1. To understand the classification of Lie algebras through Dynkin diagrams. 2. To learn various concepts of Lie Algebra theory. 3. To understand the applications of Lie algebras in Mathematics and Theoretical Physics.		
Learning Outcomes: At the end of this module the learner will be able to 1. To understand the concepts of Cartan Subalgebra and the Root Systems. 2. To study Representation Theory of Lie Algebras and the killing form and its classification. 3. To learn various applications based on Lie algebras in different field.		

2.1	**Cartan Subalgebras and Root Systems:** Definition and examples, Root space decomposition, Cartan matrix and Dynkin diagrams (basic introduction), **Representation Theory of Lie Algebras:** Modules over Lie algebras, Irreducible representations, Weight spaces and weight diagrams, **The Killing Form and Classification:** Invariant bilinear forms, The Killing form and its properties, Cartan's Criterion for semi simplicity, **Applications of Lie Algebras:** Role in differential equations and symmetries, Introduction to Lie groups (as motivation)	**[15L]**

References:

1. Humphreys, J. E.: Introduction to Lie Algebras and Representation Theory, 3/e, Springer.
2. Jacobson, N.: Lie Algebras, Reprint edition 1979, Dover, New York.
3. Hall, Brian C.: Lie Groups, Lie Algebras, and Representations, 2003, Springer.
4. Fulton and Harris: Representation Theory: A First Course, 2004, Springer.

Mapping of COs and PSOs

Course Learning Outcomes	**Programme Outcomes**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
To introduce the structure and classification of Lie algebras.	X	X	X	X	X	X	X	
To explore representations and substructures of Lie algebras.	X	X	X	X		X	X	
To familiarize nilpotent and solvable Lie algebras and prove the Engel's theorem.	X	X	X	X		X	X	
To understand theorems on Simple and Semi simple Lie algebras and their applications	X	X	X	X	X	X	X	
To derive various decomposition theorems on Lie algebras.	X	X	X	X	X	X	X	
To understand the classification of Lie algebras through Dynkin diagrams.	X	X	X	X		X	X	
To understand the applications of Lie algebras in Mathematics and Theoretical Physics.	X	X	X	X	X	X	X	X

Skill Based Course (SEC-III)

COURSE TITLE: FUZZY SETS AND LOGIC

COURSE CODE: MHMSC-S3SEC4-2CR25 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. To develop the fundamental concepts such as fuzzy sets, operations and fuzzy relations. 2. To learn about the fuzzification of scalar variables and the defuzzification of membership functions. 3. To learn images and inverse image of fuzzy sets, Fuzzy numbers and element of fuzzy arithmetic. 4. To understand the basic concepts of Fuzzy relations, Fuzzy graphs, Fuzzy logic and Fuzzy qualifiers.		
Module 1	**Fuzzy Sets**	**[15L]**
Learning Objective 1. To develop the fundamental ideas related to fuzzy sets, operations and fuzzy relations. 2. To Study the concepts of images and inverse image of fuzzy sets, Fuzzy numbers and element of fuzzy arithmetic.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the basic ideas of fuzzy sets, operations and properties of fuzzy sets and also about fuzzy relations. 2. Understand the basic features of membership functions, fuzzification process and defuzzification process.		
1.1	Fuzzy sets, Basic definitions, Alpha-cut sets, Convex fuzzy sets, Basic operation on fuzzy sets, Types of fuzzy sets, Cartesian products, Algebraic products, Bounded sum and differences, t-norms and t-corners. The extension principle, The Zadeh's extension principle, Images and inverse image of fuzzy sets, Fuzzy numbers, Element of fuzzy arithmetic.	**[15L]**
Module 2	**Fuzzy Relation and Logic**	**[15L]**
Learning Objective 1. To study the fundamental concepts of Fuzzy relation, fuzzy graphs, , Fuzzy logic and Fuzzy qualifiers.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the basic concepts of Fuzzy relations, Fuzzy graphs and Fuzzy logic and related problems based on it. 2. Learn the basic concepts of Fuzzy relations, Fuzzy propositions, Fuzzy qualifiers and related problems based on it.		
2.1	Fuzzy relation and fuzzy graphs. Fuzzy relation on fuzzy sets, composition of fuzzy relation, min-max composition and properties, equivalence relations, fuzzy compatibility relation, Fuzzy relation equations. Fuzzy logic, An overview of classical logic, Multivalued logic, Fuzzy propositions, Fuzzy qualifiers, Linguistic variables and hedge.	**[15L]**

References:

1. G. J. Klir and Bo Yuan, Fuzzy sets and Fuzzy logic, 2/e, Prentice Hall P T R, 1995.
2. H.J. Zimmermann, Fuzzy set theory and its Applications, Springer, 1991.
3. A.K. Bhargava, Fuzzy set theory, Fuzzy logic and their Applications, 1/e, Springer, 2013.
4. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer, 2004.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
To develop the fundamental concepts such as fuzzy sets, operations and fuzzy relations.	X	X	X	X	X	X	X	
To learn about the fuzzification of scalar variables and the defuzzification of membership functions.	X	X	X	X	X	X	X	
To learn images and inverse image of fuzzy sets, Fuzzy numbers and element of fuzzy arithmetic.	X	X	X		X	X	X	
To understand the basic concepts of Fuzzy relations, Fuzzy graphs, Fuzzy logic and Fuzzy qualifiers.	X	X	X	X	X	X	X	