CHAUDHARY RANBIR SINGH UNIVERSITY, JIND

(Established by the State Legislature Act 28 of 2014)

Scheme
for
Post Graduate Programme

M.Sc. Mathematics

as per NEP-2020

Curriculum and Credit Framework for Postgraduate Programme

With Multiple Entry-Exit, Internship and CBCS-LOCF

With effect from the session 2025-26 (in phased manner)

DEPARTMENT OF MATHEMATICS

FACULTY OF PHYSICAL SCIENCES

CHAUDHARY RANBIR SINGH UNIVERSITY, JIND-126102

HARYANA, INDIA

Abbreviations used

Sr. No.	Full form	Abbreviation	Description
1	Core Course	CC	Compulsory core courses for the programme. CC will be a theory course of 4 credits.
2	Discipline Elective Course	DEC	Elective Courses offered by the DCI. A student can opt one course out of 4 given options for that DEC course. One course can be opted in a semester through MOOCs from SWAYAM or other portals. DEC will be a theory course of 4 credits.
3	Practicum	PC	Practical course of 4 credits which will be compulsory in all semesters for all students except in the 4th Semester when a student opts Dissertation work.
4	Seminar	S	Seminar is a Skill Enhancement Course (SEC) aiming to impart skills of self-learning, comprehension, communication and presentation.
5	Constitutional, Human, Moral Values and IPR	CHM	CHM is a compulsory Value Added theory Course of 2 credits.
6	Open Elective Course	OEC	OEC is a Multidisciplinary course of 2 credits. Every student will opt a course from the pool of OEC courses other than Mathematics.
7	Employability and Entrepreneurship Skills Course	EEC	EEC is Vocational or SEC course aiming to increase the employment and entrepreneurship potential of students of programme.
8	Theory	Th	
9	Practical	P	
9	Lecture	L	
10	Tutorial	T	
11	Dissertation	D	A research course of 12 credits, where a student will undertake research work and submit a dissertation as per rules prescribed by the university.
12	Programme Learning Outcomes	PLOs	
13	Course Learning Outcomes	CLOs	

Programme Learning Outcomes (PLOs): As per NEP-2020, PLOs include outcomes specific to disciplinary areas of learning associated with the chosen field (s) of learning as well as generic learning outcomes. These also include transferable skills and competencies that post graduates of all programmes of study should acquire and be able to demonstrate for the award of the Degree. The programme learning outcomes would also focus on knowledge and skills that prepare students for further study, employment, research and responsible citizenship.

The PLOs of **M.Sc. Mathematics** programme are stated as per following domains:

PLOs	**After the completion of Master degree in Mathematics, a student will be able to:**
PLO-1: Knowledge and Understanding	Demonstrate the deep understanding and advanced knowledge in the core areas of Mathematics subject and understanding of recent developments and issues, including concepts, theories, principles, methods and techniques in different areas of pure and applied Mathematics.
PLO-2: General Skills	Acquire the general skills required for performing and accomplishing the tasks as expected to be done by a skilled professional in the fields of Mathematics.
PLO-3: Technical/ Professional Skills	Demonstrate the learning of advanced cognitive computing, programming, formulating models, using mathematical softwares and other teaching and professional skills required for completing the specialized tasks related to the profession and for conducting and analyzing the relevant research tasks in different domains of the Mathematics.
PLO-4: Communication Skills	Effectively communicate the attained skills in different areas of the Mathematics in a precise, well-structured and unambiguous mathematical language through effective oral and/or written expressions to the society at large.
PLO-5: Application of Knowledge and Skills	Apply the acquired knowledge and skills to the problems in the subject area, and to identify and analyze the issues where the attained knowledge and skills can be applied by carrying out research investigations to formulate evidence-based solutions to complex and unpredictable problems associated with the field of Mathematics or otherwise.
PLO-6: Critical thinking and Research Aptitude	Attain the capabilities of critical thinking, logical reasoning, investigating problems, analysis, problem solving, application of mathematical methods/techniques, in intra/inter-disciplinary areas of the **Mathematics** enabling to develop skills to solve mathematical problems having applications in other disciplines and/or in the real world and to formulate, synthesize, and articulate issues for designing of research proposals, testing hypotheses, and drawing inferences based on the analysis.
PLO-7: Constitutional, Humanistic, Moral	Know constitutional, humanistic, moral and ethical values, and intellectual property rights to become a scholar/professional with

Values and Ethics	ingrained values in expanding knowledge for the society, and to avoid unethical practices such as fabrication, falsification or misrepresentation of data or committing plagiarism.
PLO-8: Capabilities/ qualities and mindset	To exercise personal responsibility for the outputs of own work as well as of group/team and for managing complex and challenging work(s) that requires new/strategic approaches.
PLO-9: Employability and job-ready skills	Attain the knowledge and skills required for increasing employment potential, adapting to the future work and responding to the rapidly changing demands of the employers/industry/society with time, and to have strong foundation in basic and applied aspects of Mathematics so as to venture into research in different areas of mathematical sciences, jobs in scientific and various industrial sectors and/or teaching career in Mathematics.

Chaudhary Ranbir Singh University, Jind

Scheme of Examination for Postgraduate Programme M.Sc. Mathematics
as per NEP-2020 Curriculum and Credit Framework for Postgraduate Programmes
(CBCS LOCF) with effect from the session 2025-26 (in phased manner)
Framework-2
Scheme-Q

Semester	Course Type	Course Code	Nomenclature of course	Theory (Th)/ Practical (P)/ Seminar/ CHM/OEC/ EEC/ Dissertation/ Project Work	Credits		Contact hours per week L: Lecture P: Practical T: Tutorial				Internal Assessment Marks	End Term Examination Marks	Total Marks	Examination hours
					Course	Sem. Total	L	T	P	Total				
I	CC-1	M24-MAT-101	REAL ANALYSIS	Th	4	26	3	1	0	4	30	70	100	3
	CC-2	M24-MAT-102	COMPLEX ANALYSIS	Th	4		3	1	0	4	30	70	100	3
	CC-3	M24-MAT-103	ORDINARY DIFFERENTIAL EQUATIONS-I	Th	4		3	1	0	4	30	70	100	3
	CC-4	M24-MAT-104	NUMBER THEORY	Th	4		3	1	0	4	30	70	100	3
	CC-5	M24-MAT-105	ABSTRACT ALGEBRA	Th	4		3	1	0	4	30	70	100	3

	PC-1	M24-MAT-106	PRACTICAL -1	P	4		0	0	8	8	30	70	100	4
	SEMINAR	M24-MAT-107	SEMINAR	S	2		0	0	0	2	0	50	50	1
2	CC-6	M24-MAT-201	FIELD THEORY	Th	4		4	0	0	4	30	70	100	3
	CC-7	M24-MAT-202	MEASURE AND INTEGRATION	Th	4		4	0	0	4	30	70	100	3
	CC-8	M24-MAT-203	TOPOLOGY	Th	4		4	0	0	4	30	70	100	3
	CC-9	M24-MAT-204	ORDINARY DIFFERENTIAL EQUATIONS-II	Th	4	26	4	0	0	4	30	70	100	3
	CC-10	M24-MAT-205	COMPUTER PROGRAMMING WITH MATLAB	Th	4		4	0	0	4	30	70	100	3
	PC-2	M24-MAT-206	PRACTICAL-2	P	4		0	0	0	8	30	70	100	4
	CHM	M24-CHM-201	CONSTITUTIONAL, HUMAN AND MORAL VALUES, AND IPR	Th	2		2	0	0	2	15	35	50	3
	Internship	M24-INT-200	An internship course of 4 Credits of 4-6 weeks duration during summer vacation after 2nd semester is to be completed by every student. Internship can be either for enhancing the employability or for developing the research aptitude.								50	50	100	

3	CC-11	M24-MAT-301	INTEGRAL EQUATIONS AND CALCULUSOF VARIATIONS	Th	4	26	4	0	0	4	30	70	100	3
	CC-12	M24-MAT-302	FUNCTIONAL ANALYSIS	Th	4		4	0	0	4	30	70	100	3
	DEC-1 (One course is to be opted out of M24-MAT-303 to M24-MAT-306)	M24-MAT-303	FUZZY SET THEORY	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-304	COMMUTATIVE ALGEBRA	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-305	DIFFERENTIAL GEOMETRY	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-306	ELASTICITY	Th	4		4	0	0	4	30	70	100	3
	DEC-2 (One course is to be opted out of M24-MAT-307 to M24-MAT-310)	M24-MAT-307	ADVANCED NUMERICAL ANALYSIS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-308	ARTIFICIAL INTELLIGENCE	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-309	MATHEMATICAL STATISTICS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-310	FLUID MECHANICS	Th	4		4	0	0	4	30	70	100	3

	DEC-3 (One course is to be opted out of M24-MAT-311 to M24-MAT-314)	M24-MAT-311	ALGEBRAIC CODING THEORY	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-312	FINANCIAL MATHEMATICS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-313	LINEAR PROGRAMMING AND OPTIMIZATION	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-314	MATHEMATICAL MODELING	Th	4		4	0	0	4	30	70	100	3
	PC-3	M24-MAT-315	PRACTICAL-3	P	4		0	0	8	8	30	70	100	4
	OEC	M24-OEC-331	MATHEMATICAL TOOLS FOR OTHER DISCIPLINES	Th	2		2	0	0	2	15	35	50	3
4	CC-13	M24-MAT-401	PARTIAL DIFFERENTIAL EQUATIONS	Th	4		4	0	0	4	30	70	100	3
	CC-14	M24-MAT-402	DISCRETE MATHEMATICS	Th	4		4	0	0	4	30	70	100	3
	DEC-4 (One course is to be opted out of M24-	M24-MAT-403	ADVANCED COMPLEX ANALYSIS	Th	4	26	4	0	0	4	30	70	100	3
		M24-MAT-404	ALGEBRAIC NUMBER THEORY	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-405	GENERAL MEASURE AND INTEGRATION THEORY	Th	4		4	0	0	4	30	70	100	3

	MAT-403 to M24-MAT-406)	M24-MAT-406	ADVANCED FUZZY SET THEORY	Th	4		4	0	0	4	30	70	100	3
	DEC-5 (One course is to be opted out of M24-MAT-407 to M24-MAT-410)	M24-MAT-407	WAVELET ANALYSIS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-408	ADVANCED FUNCTIONAL ANALYSIS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-409	ADVANCED FLUID MECHANICS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-410	ECONOMETRICS	Th	4		4	0	0	4	30	70	100	3
	DEC-6 (One course is to be opted out of M24-MAT-411 to M24-MAT-414)	M24-MAT-411	BIO-MATHEMATICS	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-412	STATISTICAL INFERENCE AND ESTIMATION	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-413	OPERATIONS RESEARCH	Th	4		4	0	0	4	30	70	100	3
		M24-MAT-414	NON-COMMUTATIVE RINGS	Th	4		4	0	0	4	30	70	100	3
	PC-4	M24-MAT-415	PRACTICAL-4	P	4		0	0	0	8	30	70	100	4
	EEC	M24-MAT-416	EMPLOYABILITY SKILLS IN MATHEMATICS	Th	2		2	0	0	2	15	35	50	3
	OR													

	Dissertation	M24-MAT-417	DISSERTATION	D	12		0	0	0	12	0	300	300	-

NOTES:

1. A student may opt for Dissertation work of 12 credits in place of CC-14, DEC-6 and PC-4 courses in the 4th Semester.
2. The candidates, who are offered the Dissertation Course, will also study the CC-13, DEC-4, DEC-5 and EEC courses in the 4th Semester
3. A student can opt one elective course in a semester, i.e. up to 40% of total elective courses mentioned in the scheme, through SWAYAM/NPTEL or other online portals recognized by the UGC and the university.

Table-1

Course composition- Theory/ Theory +Tutorial			
Course Credit	Internal Assessment marks	End term exam marks	Total marks
2	15	35	50
4	30	70	100

Table-2: Course composition- Theory + Practical

Course Credit	Theory		Practical		Total marks
Theory +Practical	Internal Assessment marks	End term exam marks	Internal Assessment marks	End term exam marks	
2+0	15	35	-	-	50
4+0	30	70	-	-	100
0+4	-	-	30	70	100

Table- 3: Distribution of Internal Assessment Marks (Theory)

Total Internal Assessment Marks (Theory)	Class Participation	Seminar/Presentation/Assignment/Quiz/class test, etc.	Mid-Term Exam
15	4	4	7
30	5	10	15

Table -4 Distribution of Internal Assessment Marks (Practical)

Total Internal Assessment Marks (Practicum)	Class Participation	Seminar/Demonstration/Viva-Voce/Lab record, etc.	Mid-Term Exam
30	5	10	15

CC-11 INTEGRAL EQUATIONS AND CALCULUS OF VARIATIONS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	INTEGRAL EQUATIONS AND CALCULUS OF VARIATIONS
Course Code	M24-MAT-301
Course Type	CC-11
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	This course is designed to get acquainted with the concept of integral equations and the methods to find their solutions. A student will learn about integral equations, their classifications, eigen values and eigen functions, method of successive approximations, iterative methods, resolvent kernel. Fredholm three theorems are main part of the first section. In the second section, symmetric kernels, Riesz-Fisher theorem, Hilbert-Schmidt theory, solution of a symmetric integral equation, Abel`s integral equation and Cauchy type singular integral equations are learnt.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 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. CLO 2: Derive procedures 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. CLO 3: Design methods for solving the integral equations with symmetric kernels 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. CLO 4: Understand concepts calculus of variations and to solve variational problems of different forms of functionals.

	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30		30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	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. (chapters 1 and 2 of the book Ram P. Kanwal, Linear Integral Equations: Theory & Techniques).	15
II	Method of successive approximations, Iterative scheme for Fredholm and Volterra 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, Fredholm`s third theorem. (chapters 3 and 4 of the book Ram P. Kanwal, Linear Integral Equations: Theory & Techniques).	15
III	Symmetric Kernels, Complex Hilbert space. An orthonormal system of functions, Riesz-Fisher theorem, A complete two-Dimensional orthonormal set over the rectangle $a \le s \le b, c \le t \le d$. Fundamental properties of Eigenvalues and Eigenfunctions 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 ℓ_2-Kernel (not	15

	necessarily symmetric) by a separable Kernel. The operator method in the theory of integral equations. Rayleigh-Ritz method for finding the first eigenvalue. (Chapter 7 of the book Ram P. Kanwal, Linear Integral Equations: Theory & Techniques).	
IV	Functional and its variation, Euler`s (Euler-Lagrange) equations Variational problems for functionals depending on one independent and one dependent variable(s) and its (i) first derivative (ii) higher derivatives with fixed end conditions, Variational problems for functionals depending on n functions of a single independent variable and functional depending on a function and its n derivatives, Functionals dependent on functions of several independent variables. Variational problems in parametric form Natural boundary conditions and transition conditions, Invariance of Euler`s equation. Conditional extremum. Variational problem with moving boundaries. Some basic problems in calculus of variations shortest distance, minimum surface of revolution, Brachistochrone problem, isoperimetric problem and geodesic problems. (Relevant portions from the text books recommended at Sr. No. 7 & 8).	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1. Ram P. Kanwal, Linear Integral Equations: Theory & Techniques, Springer Science & Business Media, 2012.
2. S.G. Mikhlin, Linear Integral Equations (translated from Russian), Hindustan Book Agency, 1960.
3. F.G Tricomi, Integral Equations, Courier Corporation, 1985.
4. Abdul J. Jerri, Introduction to Integral Equations with Applications, Wiley-Interscience, 1999.
5. Ian N. Sneddon, Mixed Boundary Value Problems in potential theory, North Holland Publishing Co., 1966.
6. Ivar. Stakgold, Boundary Value Problems of Mathematical Physics Vol.I, II, Society for Industrial and Applied Mathematics, 2000.
7. Francis B. Hilderbrand, Methods of Applied Mathematics, Courier Corporation, 2012.
8. A.S. Gupta, Calculus of Variations with Applications, PHI Learning Pvt. Ltd., 1996.

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	FUNCTIONAL ANALYSIS
Course Code	M24-MAT-302
Course Type	CC-12
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Algebra and Real Analysis
Course Objectives	The main objective is to get familiarized with normed linear spaces, Banach spaces, inner product spaces and Hilbert spaces. The four fundamental theorems: Hahn-Banach Theorem, Uniform Boundedness Theorem, Open Mapping Theorem and Closed Graph Theorem are the highlights of this course. We also make an excursion into Hilbert spaces, introducing basic concepts and proving the classical theorems associated with the names of Riesz, Bessel and Parseval,
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Know about the requirements of a norm; completeness with respect to a norm; understand relation between compactness and dimension of a space; check boundedness of a linear operator and relate to continuity. CLO 2: Extend a linear functional under suitable conditions; apply the knowledge to prove Hahn Banach Theorem for further application to obtain the representation of bounded linear functionals on C[a,b], and demonstrate understanding of the statement and proof of uniform boundedness theorem, open mapping theorem, bounded inverse theorem and closed graph theorem. CLO 3: Understand distinguish between Banach spaces and Hilbert spaces; decompose a Hilbert space in terms of orthogonal

	complements. CLO 4: Understand totality of orthonormal sets and sequences; represent a bounded linear functional in terms of inner product.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Normed linear spaces, Banach spaces, finite dimensional normed spaces and subspaces, equivalent norms, compactness and finite dimension, F.Riesz`s lemma. Bounded and continuous linear operators, differentiation operator.(Scope as in relevant parts of Chapter 2 of „Introductory Functional Analysis with Applications` by E.Kreyszig)	15
II	Hahn-Banach theorem for normed linear spaces, application to bounded linear functionals on C[a,b], Riesz-representation theorem for bounded linear functionals on C[a,b], Uniform Boundedness Theorem, Open Mapping Theorem and Closed Graph. (Scope as in relevant parts of Chapter 4 of Introductory Functional Analysis with Applications` by E.Kreyszig)	15
III	Inner product spaces, Hilbert spaces and their examples, Schwarz inequality, continuity of inner product, orthogonal complements and direct sums, minimizing vector, orthogonality, projection theorem, characterization of sets in Hilbert spaces whose span is dense. (Scope as in relevant parts of sections 3.1 to 3.3 of Chapter 3 of Introductory Functional Analysis with Applications' by E.Kreyszig)	15

IV	Orthonormal sets and sequences, Bessel's inequality, series related to orthonormal sequences and sets, total (complete) orthonormal sets and sequences, Parseval's identity, separable Hilbert spaces. (Scope as in relevant parts of sections 3.4 to 3.6 of Chapter 3 of „Introductory Functional Analysis with Applications' by E.Kreyszig) Riesz representation theorem for bounded linear functionals on a Hilbert space, sesquilinear form, Riesz representation theorem for bounded sesquilinear forms on Hilbert spaces. (Scope is as in relevant parts of sections 3.8 to 3.10 of Chapter 3 of Introductory Functional Analysis with Applications' by E.Kreyszig)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Book:

1. E.Kreyszig: Introductory Functional Analysis with Applications, Wiley India, 2007.

Reference Books:

1. G.F.Simmons: Introduction to Topology and Modern Analysis, McGraw Hill Book Co.,New York, 1983.

2. C.Goffman and G.Pedrick: First Course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.

3. G.Bachman and L.Narici, Functional Analysis, Dover Publications, 2000.

4. L.A.Lustenik and V.J.Sobolev, Elements of Functional Analysis, Hindustan Publishing Corporation New Delhi, 1971.

5. J.B.Conway: A Course in Functional Analysis, Springer-Verlag, 1990.

6. P.K.Jain, O.P.Ahuja and Khalil Ahmad: Functional Analysis, Second Edition, New Age International(P) Ltd. & Wiley Eastern Ltd., New Delhi, 2010.

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	FUZZY SET THEORY
Course Code	M24-MAT-303
Course Type	DEC-1
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	The course aims to provide students with a thorough understanding of fuzzy sets and their applications. It covers basic concepts such as a-cuts, strong a-cuts, level sets, and fuzzy set operations, including standard complement, intersection, and union. Students will learn about the additional properties of fuzzy sets, including decomposition theorems and the extension principle. The course also focuses on the operations on fuzzy sets, including fuzzy complements, fuzzy intersections, and t-norms, along with the characterization of fuzzy numbers. Additionally, it explores the relationships between fuzzy numbers and convex fuzzy sets, the arithmetic operations on fuzzy numbers, and the conversion between decreasing and increasing generators, equipping students to apply fuzzy logic in various practical scenarios.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Students will be able to define and understand the basic concepts of fuzzy sets, including a-cuts, strong a-cuts, level sets, support, core, and height of a fuzzy set. CLO 2: Students will understand the additional properties of a-cuts, including their involvement in the standard fuzzy set operators and fuzzy set inclusion. CLO 3: Students will be able to identify and apply different types of operations on fuzzy sets, such as fuzzy complements and equilibrium conditions of a fuzzy complement. Students will learn about decreasing generators, increasing generators, and their Pseudo-inverses, along with examples of t-norms and drastic intersections. CLO 4: Students will develop a deep understanding of fuzzy numbers and their relationship with convex fuzzy sets, including the use of membership functions as piecewise defined functions.

	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Fuzzy Sets: Basic definitions, a-cuts, strong a-cuts, level set of a fuzzy set, support of a fuzzy set, the core and height of a fuzzy set, normal and subnormal fuzzy sets, convex fuzzy sets, cutworthy property, strong cutworthy property, standard fuzzy set operations, standard complement, equilibrium points, standard intersection, standard union, fuzzy set inclusion, scalar cardinality of a fuzzy set, the degree of subsethood.	15
II	Additional properties of a-cuts involving the standard fuzzy set operators and the standard fuzzy set inclusion. Representation of fuzzy sets, three basic decomposition theorems of fuzzy sets, Extension principle for fuzzy sets, Images and inverse images of fuzzy sets, proof of the fact that the extension principle is strong cutworthy but not cutworthy.	15
III	Operators on fuzzy sets: types of operations, fuzzy complements, equilibrium of a fuzzy complement, equilibrium of a continuous fuzzy complement, first and second characterization theorems of fuzzy complements, fuzzy intersections (t-norms), standard fuzzy intersection as the only idempotent t-norm, standard intersection, algebraic product, bounded difference and drastic intersection as examples of t-norms, decreasing generator, the Pseudo-inverse of a decreasing generator, increasing generators and their Pseudo-inverses.)	15

IV	Conversion of decreasing generators and increasing generators to each other, characterization theorem of t-norms (statement only), fuzzy unions (t-conorms), standard union, algebraic sum, bounded sum, and drastic union as examples of t-conorms, characterization theorem of t-conorms (statement only). Fuzzy numbers, relation between fuzzy numbers and a convex fuzzy set, characterization of fuzzy numbers in terms of its membership functions as piecewise defined functions, fuzzy cardinality of a fuzzy set using fuzzy numbers, arithmetic operators on fuzzy numbers, extension of standard arithmetic operations on real numbers to fuzzy numbers.	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Book:

1. 1. G. J. Klir and B. Yuan: Fuzzy Sets and Fuzzy: Logic Theory and Applications, Prentice Hall of India, 2008

Reference Books:

1. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer International Edition, 2005.
2. H.J. Zimmerman, Fuzzy Set Theory and its Applications, Allied Publishers Ltd., New Delhi, 1991.
3. John Yen, Reza Langari, Fuzzy Logic - Intelligence, Control and Information, Pearson Education, 1999.
4. A.K. Bhargava, Fuzzy Set Theory, Fuzzy Logic & their Applications, S. Chand & Company Pvt. Ltd., 2013.

DEC-I COMMUTATIVE ALGEBRA

With effective from the Session: 2025-26

Part A – Introduction

Name of Programme	M.Sc. Mathematics		
Semester	III		
Name of the Course	COMMUTATIVE ALGEBRA		
Course Code	M24-MAT-304		
Course Type	DEC-1		
Level of the course	500-599		
Pre-requisite for the course (if any)	Courses on Abstract Algebra up to the 499 level		
Course Objectives	The course is designed to give an exposure of the concepts in commutative rings and modules defined on commutative rings. The course contains exact sequences of modules, primary decomposition of an ideal. This course also contains Integrally closed domains, comaximal, Chinese remainder theorem, local rings, primary decomposition of an ideal in Notherian rings.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Learn about free modules, rank of Module, projective modules. CLO 2: Learn about ideals, local rings. CLO 3: Understand Noetherian modules, primary decomposition, Artinian modules. CLO 4: Understand integral elements, integral extensions, integrally closed domains, finiteness of integral closure.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100		
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Free module, submodules, cyclic modules, homomorphism of R-modules, rank of Module. projective modules, Shanuel`s lemma.	15
II	Ideals, maximal ideals, prime ideals, nilpotent elements, comaximal Chinese remainder theorem, local rings, Nakayama lemma.	15
III	Noetherian modules, Hilbert`s basis theorem, primary ideal, primary decomposition. first and second uniqueness theorem, Artinian modules.	15
IV	Integral elements, integral closure, integral extensions, lying above going up theorem, integrally closed domains, going-down theorem finiteness of integral closure.	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. N.S.Gopal Krishnan : Commutative Algebra , Orient Blackswan Private Limited, 2017.

Reference books:

1. M.F.Atiyah and I.G.Macdonald : Introduction to Commutative Algebra, Addison-Wesley Publishing Company, 1969.

2. O. Zariski and P. Samuel : Commutative Algebra I, Springer, Volume 28, 1975.

DEC-1 Differential Geometry

With effective from the Session: 2025-26			
Part A – Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	III		
Name of the Course	Differential Geometry		
Course Code	M24-MAT-305		
Course Type	DEC-1		
Level of the course	500-599		
Pre-requisite for the course (if any)	Courses on Differential and Vector Calculus		
Course Objectives	Differential geometry is a discipline that uses the techniques of differential calculus, vector calculus and linear algebra to study problems in geometry and the mathematical analysis of curves and surfaces in space is studied in this course. The objective is to learn about curves in space and other related concepts; surfaces, envelopes, developable surfaces; curves on surfaces; and Geodesics.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concepts of curves in space and other related concepts like tangent, principal normal, curvature, binormal, torsion, centre of curvature, spherical curvature, involutes, evolutes, Bertrand curves and to solve related problems. CLO 2: Understand and distinguish surfaces and their characteristics, developable surfaces, family of surfaces and curvilinear coordinates. Demonstrate knowledge to solve related problems of geometry. CLO 3: Learn about curves on surfaces, conjugate systems, asymptotic lines, isometric lines, null lines etc. and minimal curves. CLO 4: Derive equations of Gauss and Codazzi, Mainardi-Codazzi relations and Bonnet`s theorem. Understand concepts of geodesics and curves in relation to geodesics and apply knowledge in problem solving.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Curves: Tangent, principal normal, curvature, binormal, torsion, Serret-Frenet formulae, locus of center of curvature, spherical curvature, locus of centre of spherical curvature, curve determined by its intrinsic equations, helices, spherical indicatrix of tangent, etc., involutes, evolutes, Bertrand curves.	15
II	Envelopes and Developable Surface : Surfaces, tangent plane, normal. One parameter family of surfaces; Envelope, characteristics, edge of regression, developable surfaces. Developables associated with a curve; Osculating developable, polar developable, rectifying developable. Two parameter family of surfaces; Envelope, characteristic points and examples. Curvilinear Coordinates, First order magnitudes, directions on a surface, the normal, second order magnitudes, derivatives of **n**, curvature of normal section, Meunier`s theorem.	15
III	Curves on a surface: Principal directions and curvatures, first and second curvatures, Euler`s theorem, Dupin`s indicatrix, the surface z = f(x, y), surface of revolution. Conjugate systems; conjugate directions, conjugate systems. Asymptotic lines, curvature and torsion. Isometric lines, isometric parameters. Null lines, minimal curves.	15
IV	The equations of Gauss and of Codazzi: Gauss`s formulae for $r_{11}$, $r_{12}$, $r_{22}$, Gauss characteristic equation, Mainardi-Codazzi relations, alternative expression, Bonnet`s theorem, derivatives of the angle ω. Geodesics: Geodesic property, equations of geodesics, surface of revolution, torsion of a geodesic. Curves in relation to Geodesics; Bonnet`s theorem, Joachimsthal`s theorems, vector curvature, geodesic curvature, Bonnet`s formula..	15
	Total Contact Hours	60

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	

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• Seminar/presentation/assignment/quiz/class test etc.:	10	
• Mid-Term Exam:	15	

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. 1. C.E. Weatherburn, Differential Geometry of Three Dimensions, Radha Publishing House, Calcutta, 1988.

Reference books:

1. John A. Thorpe, Elementary Topics in Differential Geometry, Springer Science & Business Media, 1994.
2. B.O. Neill, Elementary Differential Geometry, Academic Press, 1997.
3. Erwin Kreyszig, Differential Geometry, Dover Publications, 2013.
4. S. Sternberg, Lectures on Differential Geometry, Reprinted by AMS, 2016.
5. Nirmala Prakash, Differential Geometry, Tata McGraw-Hill Publishing Company Limited, 1992.
6. R.S. Millman and G.D. Parker, Elements of Differential Geometry, Prentice-Hall, 1977.

DEC-1 ELASTICITY

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	ELASTICITY
Course Code	M24-MAT-306
Course Type	DEC-1
Level of the course	500-599
Pre-requisite for the course (if any)	Course on Mechanics of Solids
Course Objectives	This paper deals with elastostatics problems on extension, torsion, bending and flexure of beams through the application of forces and couples. The techniques used to solve these problems involve the applications of complex analysis (analytic functions, conformal mappings) as well. The boundary value problems arising in plane elasticity are solved for analytical solutions. Some techniques of solving the three-dimensional elastodynamics problems are also discussed.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concepts of extension and torsion and learn to solve different elastostatics problems of extension and torsion of beams. CLO 2: Learn techniques to make use of complex analysis (analytic functions, conformal mappings) for solving elastostatics problems. Be familiar with flexure of beams of different cross-sections. CLO 3: Understand plane deformation, plain stress and Airy Stress function and attain capability to solve two dimensional problems in elasticity for analytical solutions. CLO 4: Learn techniques for solving some scientifically important elastodynamics problems in three-dimensions and understand vibrations of elastic solids and wave propagation in such solids.

Credits	Theory	Practical	Total
	4	0	4

Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Extension: Extension of beams by longitudinal forces, Beam stretched by its own weight, Bending of beams by terminal couples. Torsion: Torsion of a circular shaft, Torsion of cylindrical bars, Torsional rigidity. Torsion and stress functions. Lines of shearing stress. Torsion of an elliptic cylinder. Simple torsion problems, effect of grooves. (Relevant sections 30–37 of Chapter 4 of the book recommended at Sr. No. 1)	15
II	Torsion of rectangular beam, Torsion of a triangular prism. Solution of torsion problems by means of conformal mapping. Torsion-membrane analogy, Torsion of hollow beams, Torsion of anisotropic beams. Flexure of beams by terminal loads, Flexure of circular and elliptic beams, Bending of rectangular beams, Bending of circular pipes. (Relevant sections 38, 44-47, 51-57, 59; Chapter 4 of the book recommended at Sr. No. 1)	15
III	Two dimensional problems: Plane deformation, Generalized plane stress, Plane elastostatic problems. Airy stress function. General solution of biharmonic equation, Stresses and displacements in terms of complex potentials. The structure of functions $\varphi(z)$ and $\psi(z)$. First and second boundary value problems in plane elasticity. Existence and uniqueness of the solutions. (Relevant sections 65-74 of Chapter 5 of the book recommended at Sr. No. 1)	15
IV	Three dimensional problems: General solutions; Concentrated forces; Deformation of elastic half-space by normal loads; The problem of Boussinesq. Elastic sphere: pressures, harmonics, equilibrium. Betti`s Integration method. Vibrations of elastic solids, Wave propagation in infinite regions, Surface waves. (Relevant sections 90-97, 102-104 of Chapter 6 of the book recommended at Sr. No. 1)	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

3. I.S. Sokolnikoff, Mathematical Theory of Elasticity, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1977.

Reference Books:

1. A.E.H. Love, A Treatise on the Mathematical Theory of Elasticity Dover Publications, New York.
2. Y.C. Fung. Foundations of Solid Mechanics, Prentice Hall, New Delhi, 1965.
3. D.S. Chandrasekharaiah and L. Debnath, Continuum Mechanics, Academic Press, 1994.
4. S. Timoshenko and N. Goodier. Theory of Elasticity, McGraw Hill, New York, 1970.
5. I.H. Shames, Introduction to Solid Mechanics, Prentice Hall, New Delhi, 1975.

DEC-2 ADVANCED NUMERICAL ANALYSIS

With effective from the Session: 2025- 26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	ADVANCED NUMERICAL ANALYSIS
Course Code	M24-MAT-307
Course Type	DEC-2
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Numerical Analysis
Course Objectives	This course considers the high-end numerical methods, which are often required to get the numerical results from research studies in applied sciences and engineering. The objective of the course is to equip learners with specialized tools for solving transcendental and polynomial equations, system of linear equations, eigen-value problems, numerical differentiation, numerical integration, ordinary/partial differential equations so as to enable them to draw the algorithm of these numerical methods that form the basis to write source programs in any programming language.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Learn about errors which arise during computation due to roundoff or truncation or number representation and the high-end numerical methods for solving transcendental and polynomial equations. CLO 2: Attain the skills of solving system of linear equations using direct and iterative schemes and analysis of such schemes. Know to apply finite difference schemes/operators for numerical differentiation. CLO 3: Learn advanced numerical methods to evaluate integrals for solving linear/non-linear first/second order IVP/BVP involving ODEs . CLO 4: Understand the finite difference methods for solving parabolic, elliptic and hyperbolic PDEs and attain capability to use such methods in scientific problem solving.

Credits	Theory	Practical	Total
	4	0	4

Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Error Analysis: Errors, Absolute, relative and percentage errors; Significant digits and numerical instability, Propagation of errors in arithmetic operations, Significant errors, Representation of numbers in computer, Normalized floating point representation and its effects. **Solution of Polynomial and Transcendental Equations**: Iteration methods; First order, second order and higher order methods, Accelaration of the convergence, Efficiency of a method, Newton-Raphson method for multiple roots, Modified Newton-Raphson method, Muller method and Chebyshev method, Birge-Vieta method, Bairstow method, Graeffe`s root squaring method, Solutions of systems of non-linear equations.	15
II	**Systems of Linear Equations:** Matrix inverse methods, Triangularization method, Cholesky Method, Matrix partition method, Operation count, Ill-conditioned linear systems, Least square solutions for inconsistent systems. Iteration methods, Successive over relaxation (SOR) method, Convergence analysis. Eigen values and eigen vectors, bounds on eigen values, Given's method, Householder`s method for symmetric matrices, Power method. Numerical Differentiation based on difference formulae, Richardson`s extrapolation method, Cubic spline method, Method of undetermined coefficients.	15
III	**Numerical Integration**: Weddle`s rule, Newton-Cotes method, Gauss-Legendre, Gauss-Chebyshev, Gauss-Laguerre, and Gauss-Hermite integration methods. Composite integration method. **Numerical Solution of Ordinary Differential Equations**: Estimation of local truncation error of Euler and single step methods. Bounds of local truncation error and convergence analysis of multistep methods, Adams-Bashforth methods, Adams-Predictor-Corrector methods;	15

	Moulton formula, Milne-Simpson method, System of Differential Equations.	
IV	**Solving Partial Differential Equations**: Finite difference approximations to partial derivatives, solving parabolic equations using implicit and explicit formulae, C-N scheme and ADI methods; solving elliptic equations using Gauss-elimination, Gauss-Seidel method, SOR method, and ADI method.	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. Gupta R K, Numerical Methods: Fundamentals and Applications,Cambridge University Press 2019.
2. Gupta, R. S., Elements of Numerical Analysis, Cambridge Univ. Press, 2015.
3. Jain, M. K., Iyengar, S.R.K. and Jain, R.K., Numerical Methods for Scientific and Engineering Computation, 6th Edition, New Age International Publishers, 2012.
4. Pal, M., Numerical Analysis for Scientists and Engineers, Narosa Publishing House Pvt. Ltd., 2008.

Reference books;

5. Mathews, John H. and Fink Kurtis D., Numerical Methods Using Matlab, Fourth edition; PHI Learning Private Ltd., 2015.
6. Gourdin, A. and Boumahrat, M., Applied Numerical Methods, PHI Learning Private Ltd., 2004.

DEC-2 ARTIFICIAL INTELLIGENCE

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	Artificial Intelligence
Course Code	M24-MAT-308
Course Type	DEC-2
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	This course aims to provide a thorough understanding of the fundamental concepts of Artificial Intelligence (AI) and various methods of knowledge representation essential for intelligent systems. It seeks to familiarize students with different search strategies, including both uninformed and informed techniques, for solving complex problems efficiently. The course also focuses on the architecture, characteristics, and development of production systems and expert systems, highlighting their significance in real-world applications. Additionally, it introduces students to the principles and applications of genetic algorithms and explores key challenges and methodologies in Natural Language Processing (NLP), preparing them to develop AI solutions capable of interacting intelligently with human language.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the foundations of Artificial Intelligence, including predicate logic, knowledge representation through networks, frames, and scripts. CLO 2: Apply various search strategies and algorithms to solve AI problems, and evaluate their computational properties. CLO 3: Design and analyze production systems and expert systems, utilizing probabilistic and fuzzy reasoning methods. CLO 4: Explain different learning techniques in AI and apply Natural Language Processing methods for language understanding tasks.

	Theory	Practical	Total
Credits			
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30		30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Introduction: Background, Overview of AI applications. The predicate calculus: Syntax and semantic for propositional logic and FOPL. Clause form, inference rules, resolution and unification. Knowledge representation: Network representation through Associative network & conceptual graphs. Structured representation: Frames & Scripts.	15

II	Search strategies: Strategies for state space search - data driven and goal driven search. Search algorithms: Uninformed search (Depth first search, Breadth first search) and informed search (Hill climbing, Best first, A* algorithm, Min-Max). Computational complexity. Properties of search algorithms (Admissibility, Monotonicity, Optimality, Dominance).	15
III	Production system: Definition, Types of production system (Commutative, Non-commutative, Decomposable, Non-decomposable, Linear, Non-linear) and production systems. Expert System: Characteristics, Architecture, Development, Types of expert systems, Bayesian probability theory, Stanford certainity factor model, Reasoning with belief, Fuzzy logic, Dempster/Shafer and other approaches to reasoning.	15
IV	Knowledge acquisition: Definition of Knowledge, Types of learning (Learning by automata, Genetic algorithms, Inductive learning, Learning by analogy). Natural Language Processing (NLP): Problems in understanding natural languages, Different stages of language analysis, Chomsky Hierarchy of formal languages, Transition network parsers (TNP), Augmented Transition Network Parsers (ATNP).	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books:

1. George F. Luger, Artificial Intelligence, Pearson Education, 5th Edition.
2. Dan W. Patterson, Introduction to Artificial Intelligence and Expert Systems, PHI, 1st Edition.
3. Ben Coppin, Artificial Intelligence Illuminated, Narosa Publishing House, 1st Edition.
4. Eugene Charniak and Drew McDermott, Introduction to Artificial Intelligence, Pearson Education, 2016.
5. Nils J. Nilsson, Principles of Artificial Intelligence, Narosa Publishing House, 1st Edition.

DEC-2 MATHEMATICAL STATISTICS

With effective from the Session: 2025- 26			
Part A – Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	III		
Name of the Course	Mathematical Statistics		
Course Code	M24-MAT-309		
Course Type	DEC-2		
Level of the course	500-599		
Pre-requisite for the course (if any)			
Course Objectives	This course aims to develop a rigorous understanding of the concepts of probability and various types of probability distributions. It lays the foundation for modeling random processes and analyzing statistical data. Students will learn to compute and interpret expectations, moments, joint distributions, and important limit theorems that form the basis of statistical inference.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Students will be able to understand foundational probability concepts and their theoretical properties. CLO 2: Identify and analyze discrete and continuous probability distributions. CLO 3: Work with multivariate distributions, joint densities, and transformations. CLO 4: Apply limit theorems such as the Law of Large Numbers and Central Limit Theorem.		
	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70

Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	**Foundations of Probability and Random Variables** Basic concepts of set theory: sample space, events, algebra of events. Definitions of probability: classical, empirical, and axiomatic. Addition and multiplication theorems, independent events. Conditional probability and Bayes' theorem with applications. Random variables: discrete and continuous; probability mass function (PMF), probability density function (PDF), and cumulative distribution function (CDF). Functions of random variables.	15
II	**Mathematical Expectation and Standard Distributions** Mathematical expectation and its properties. Moments, moment generating functions (MGF), cumulants. Inequalities: Markov's inequality, Chebyshev's inequality, Jensen's inequality. Discrete distributions: Bernoulli, Binomial, Poisson, Geometric, Hypergeometric, Negative Binomial – definitions, properties, and applications. Continuous distributions: Uniform, Exponential, Normal, Gamma, Beta – derivations, characteristics, and real-life relevance.	15
III	**Joint and Marginal Distributions** Bivariate and multivariate random variables. Joint, marginal, and conditional distributions for discrete and continuous cases. Independence of random variables. Covariance, correlation, and properties of the correlation coefficient. Conditional expectation and its applications. Bivariate normal distribution: definition and properties.	15
IV	**Distribution of Functions of Random Variables and Limit Theorems** Distribution of sums, differences, and other functions of random variables. Method of transformation and Jacobian technique. Convolution and distributions of sums of independent variables. Weak and strong laws of large numbers: statements and applications. Central Limit Theorem (CLT): Lindeberg–Levy version and examples.	15

		Total Contact Hours	60
Suggested Evaluation Methods			
Internal Assessment: 30		End Term Examination: 70	
➢ Theory	30	➢ Theory:	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		
Part C-Learning Resources			

Recommended Books/e-resources/LMS:

Recommended Book:

1. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 2014.

Reference book:

1. R.V. Hogg, J.W. McKean and A.T. Craig, *Introduction to Mathematical Statistics*, Pearson, 2019.
2. R.J. Larsen and M.L. Marx, *An Introduction to Mathematical Statistics and its Applications*, Prentice Hall, 2012.

Course Learning (CLOs)
After completing this learner will be able to

DEC-2 FLUID MECHANICS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Program	M.Sc. Mathematics
Semester	III
Name of the Course	FLUID MECHANICS
Course Code	M24-MAT-310
Course Type	DEC-2
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	Fluid mechanics is a branch of continuum mechanics which deals with mechanics of fluids (liquids and gases) of ideal and viscous types. Fluid mechanics has a wide range of applications in the areas of mechanical engineering, civil engineering, chemical engineering, geophysics, astrophysics, and biology. This course aims to provide basic concepts, laws and theories of fluid dynamics and to prepare a foundation to understand the motion of fluid and develop concept, models and techniques which enables to solve the two and three dimensional problems of fluid flow and help in advanced studies and research in the broad area of fluid motion.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Be familiar with continuum model of fluid flow, classify fluid/flows, Stream, path and streak lines, rotational and irrotational motion. Understand Eulerian and Lagrangian descriptions of fluid motion, law of conservation of mass and boundary surfaces. Attain ability to derive equation of continuity and problem solving. CLO 2: Learn to derive equations of motion, Bernouli equation, vorticity equation corresponding to different problems of fluid dynamics and to solve those equations. Prove theorems on circulation and energy in fluid flow. Make strong foundation for doing research in the area of fluid mechanics and bio-mechanics. CLO 3: Understand motion of sphere in a fluid and fluid flow past a sphere at rest; sources, sinks, doublets and their images. Learn to solve three dimensional flow problems of fluid
	dynamics. CLO 4: Understand two dimensional flow problems, stream function, axi-symmetric flow, complex potential, source, sink and doublets in two dimensions, Milne-Thomson circle theorem, Blasius theorem. Attain skills to solve fluid flow problems in two dimensions. Get exposure to research problems in fluid dynamics.

	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours

I	Kinematics of fluid in motion: Real fluids and ideal fluids, Velocity at a point of a fluid. Lagrangian and Eulerian methods. Stream lines, Path lines and Streak lines. Vorticity and Circulation, Vortex lines, Velocity potential, Irrotational and rotational motions. Acceleration at a point of fluid, Local and particle rates of change. Equation of continuity. Raynold's Transport Theorem. Rates of change of material integrals. Analysis of local fluid motion. (Relevant portions from the recommended text books at Sr. No. 1 & 2)	15
II	Properties of fluids. Boundary Conditions, Boundary surfaces. Equation of Motion: Lagrange's and Euler's equations of Motion. Bernoulli's equation, Applications of the Bernoulli Equation in one–dimensional flow problems, Steady motion under conservative body forces. Kelvins circulation theorem, Vorticity equation. Energy equation for incompressible flow. Kinetic energy of irrotational flow. Kelvins minimum energy theorem. Mean value of the velocity potential. Kinetic energy of infinite liquid. Uniqueness theorems. (Relevant portions from the recommended text books at Sr. No. 1 & 2)	15
III	Axially symmetric flows. Sphere at rest in a uniform stream, Sphere in motion in fluid at rest at infinity. Equation of motion of a sphere. Kinetic energy generated by impulsive motion. Motion of two concentric spheres. Three-dimensional sources, sinks and doublets. Images of sources, sinks and doublets in rigid impermeable infinite plane and in impermeable spherical surfaces. (Relevant portions from the recommended text books at Sr. No. 1 & 2)	15
IV	Two-dimensional flows: Use of cylindrical polar coordinates, Stream function, Some fundamental stream functions, Axisymmetric flow Equations satisfied by Stokes's stream function in irrotational flow Basic Stokes's stream functions, Boundary conditions satisfied by the stream function. Irrotational plane flows: Complex potential, Image systems in plane flows. Milne-Thomson circle theorem. Circular cylinder in uniform stream with circulation. Blasius theorem. (Relevant portions from the recommended text books at Sr. No. 1 & 2)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		

• Mid-Term Exam:	15

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Books;

1. F. Chorlton, *Text-book of Fluid Dynamics*, CBS Publishers and Distributors Pvt. Ltd., 2018.
2. Michael E. O`Neill and F. Chorlton, *Ideal and Incompressible Fluid Dynamics*, Ellis Horwood, 1986.

Reference Books:

1. G.K. Batchelor, *An Introduciton to Fluid Dynamics*, Cambridge University Press, 2000.
2. A.J. Chorin and A. Marsden, *A Mathematical Introduction to Fluid Dynamics*, Springer-Verlag, New York, 1993.
3. L.D. Landau and E.M. Lifshitz, *Fluid Mechanics*, Pergamon Press, 1987.
4. H. Schlichting, *Boundary Layer Theory*, Springer, 2016.
5. S. W. Yuan, *Foundations of Fluid Mechanics*, Prentice Hall of India Ltd., 1988.
6. A.D. Young, *Boundary Layers*, AIAA Education Series, Washington DC, 1989.
7. W.H. Besant and A.S. Ramsey, *A Treatise on Hydromechanics*, Part-II, CBS Publishers, Delhi, 2006.

DEC-3 ALGEBRAIC CODING THEORY

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	ALGEBRAIC CODING THEORY
Course Code	M24-MAT-311
Course Type	DEC-3
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Abstract Algebra and Field theory up to the 499 level

Course Objectives	The course contains systematic study of coding and communication of messages. This course is concerned with devising efficient encoding and decoding procedures using modern algebraic techniques. The course begins with basic results of error detection and error correction of codes, thereafter codes defined by generator and parity check matrices are given. The course also contains polynomial codes, Hamming codes, construction of finite fields and thereafter the construction of BCH codes. Linear codes, MDS codes, Reed-Solomon codes, Perfect codes, Hadamard matrices and Hadamard codes are also the part of the course.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand group codes, matrix encoding techniques, polynomial codes and Hamming codes. CLO 2: Have deep understanding of finite fields, BCH codes CLO 3: Learn about linear codes, cyclic codes, self dual binary cyclic codes. CLO 4: Learn about MDS codes, Hadamard matrices and Hadamard codes.

	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100		
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Group codes, elementary properties, matrix encoding techniques generator and parity check matrices, polynomial codes. Vector space and polynomial ring, binary representation of numbers, Hamming codes. (Chapter 1, 2 & 3 of recommended book at Sr. No. 1)	15
II	Basic properties of finite fields, irreducible polynomial over finite field, roots of unity. (7.1 to 7.3 of recommended book at Sr. No. 2) Some examples of primitive polynomials, BCH codes. (Chapter 4 of recommended book at Sr. No. 1)	15

III	Linear codes, generator and parity check matrices, dual code of a linear code, Weight distribution of the dual code of a binary linear code, new codes obtained from given codes, cyclic codes, check polynomials, BCH and Hamming codes as cyclic codes, Non-binary Hamming codes, Idempotent , solved examples and invariance property, cyclic codes and group algebras, self dual binary cyclic codes. (Chapter 5, 6 of recommended book at Sr. No. 1)	15
IV	Necessary and sufficient condition for MDS codes, the weight distribution of MDS codes, an existence problem, Read Solomon codes Hadamard matrices and Hadamard codes.(Chapter 9 and 11 of recommended book at Sr. No. 1)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books:

1. L.R. Vermani, Elements of Algebraic Coding Theory, CRC Press, 1996.
2. Steven Roman, Coding and Information Theory, Springer-Verlag, 1992.
3. W.C. Huffman and V. Pless, *Fundamentals of Error-Correcting Codes*, Cambridge University Press, 2003.
4. S. Lin and D.J. Costello, *Error Control Coding: Fundamentals and Applications*, Pearson, 2004.
5. R. McEliece, *The Theory of Information and Coding*, Cambridge University Press, 2002 (2nd Edition).
6. Tom Richardson and Rüdiger Urbanke, *Modern Coding Theory*, Cambridge University Press, 2008.

DEC-3 Financial Mathematics

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	Financial Mathematics
Course Code	M24-MAT-312
Course Type	DEC-3
Level of the course	500-599
Pre-requisite for the course (if any)	Algebra, Calculus, Partial Differential Equations
Course Objectives	No one can deny the fact that financial markets play a fundamental role in economic growth of nations by helping efficient allocation of investment of individuals to the most productive sectors of the economy. Financial sector has seen enormous growth over the past thirty years in the developed world. This growth has been led by the innovations in products referred to as financial derivatives that require great deal of mathematical sophistication and ingenuity in pricing and in creating an insurance or hedge against associated risks. Hence, this course is for anyone who is interested in the applications of finance, particularly advanced /latest business techniques. Students are required to know elementary calculus (derivatives and partial derivatives, finding maxima or minima of differentiable functions of one or more variables, Lagrange multipliers, the Taylor formula and integrals), probability (random variables and probability (binomial & normal) distributions, expectation, variance and covariance, conditional probability and independence) and linear algebra (systems of linear equations, add, multiply, transpose and invert matrices, and compute determinants).
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the fundamentals of financial mathematics through derivatives, payoff functions, options, trader types, asset price models, random walks/ motion, no-arbitrage and relevant formula/simulation /hypothesis. CLO 2: Use the Black-Scholes analysis for European options, risk neutrality, delta hedging, trading strategy involving options, along with the variations on Black-Scholes models for options on dividend-paying assets, warrants and futures. CLO 3: Solve Black-Scholes equation using Monte-Carlo method, binomial methods, finite difference methods including fast algorithms for solving linear systems and design free boundary value problem, linear complementary

	problem, fixed domain problem for American option to be solved with projective/implicit methods. CLO 4: Work on exotic options, path-dependent options, derivatives through bond models and interest rate models, convertible bonds and to learn stochastic calculus for its use in Brownian motion, stochastic integrals, stochastic differential equations and diffusion process.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Fundamentals of Financial Mathematics: Financial Markets, derivatives; Payoff functions, Options, Types of traders Asset Price Models: Discrete/continuous models and their solutions; Random walks; The Brownian motion; Ito`s formula; Simulation of asset price model; Hypothesis of no-arbitrage-opportunities; Basic properties of option prices.	15
II	Black-Scholes Analysis: The Black-Scholes Equation; Exact solution for European options; Risk Neutrality; The delta hedging; Trading strategy involving options. Variations on Black-Scholes models: Options on dividend-paying assets; Warrants; Futures and futures options.	15
III	Numerical Methods (Solving B.S equation): Monte Carlo method; Binomial Methods; Finite difference methods; Fast algorithms for solving linear systems; American Option: free boundary value problem; linear complementary problem; fixed domain problem; Projective/implicit method for American put/call.	15
IV	Exotic Options: Binaries; Compounds; Chooser options; Barrier option; Asian/lookback options; Path-Dependent Options: Average strike options; Lookback Option	15

	Bonds and Interest Rate Derivatives: Bond Models; Interest models; Convertible Bonds Stochastic calculus: Brownian motion; Stochastic integral; Stochastic differential equation; Diffusion process.	
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. Sheldon M. Ross, An Introduction to Mathematical Finance, Cambridge Univ. Press.
2. Robert J. Elliott and P. Ekkehard Kopp. Mathematics of Financial Markets, Springer-Verlag, New York Inc.
3. Robert C. Marton, Continuous-Time Finance, Basil Blackwell Inc.
4. Daykin C.D., Pentikainen T. and Pesonen M., Practical Risk Theory for Actuaries, Chapman & Hall.

DEC-3 LINEAR PROGRAMMING AND OPTIMIZATION

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	LINEAR PROGRAMMING AND OPTIMIZATION
Course Code	M24-MAT-313
Course Type	DEC-3
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	The primary objective of this course is to develop mathematical modeling and analytical skills among students for solving real-world problems involving resource allocation and decision-making. It introduces fundamental techniques of linear programming, such as simplex, duality, transportation and assignment problems, and game theory to derive optimal or near-optimal solutions under given constraints.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Define and explain the basic concepts of Operations Research, including its nature, scope, and necessity. Formulation of Linear Programming Problems CLO 2: Understand basic feasible solutions, standard and canonical forms of LPP. Simplex method: simplex tableau, pivoting, optimality test. CLO 3: Optimize resource allocation using transportation and assignment models. CLO 4: Analyze strategic interactions using two-person zero-sum game theory.

	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30		30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	**Introduction to Operations Research and Linear Programming** Nature, scope, and phases of operations research; areas of application. Formulation of Linear Programming Problems (LPP): decision variables, objective function, and constraints. Graphical solution method for LPPs with two variables: feasible region, corner-point method. Characteristics of feasible solutions, bounded/unbounded regions, degeneracy. Introduction to convex sets and their role in LPP.	15
II	**Simplex Method and Duality** Introduction to basic feasible solutions, standard and canonical forms of LPP. Simplex method: simplex tableau, pivoting, optimality test. Special cases: degeneracy, unbounded solutions, multiple solutions. Artificial variable techniques: Big-M method and Two-Phase method. Duality in linear programming: formulation of the dual, primal-dual relationships. Dual Simplex method and economic interpretation of dual variables.	15
III	**Transportation and Assignment Problems** Introduction to transportation problems: formulation and balanced/unbalanced cases. Initial basic feasible solution methods: North-West Corner Rule, Least Cost Method, Vogel's Approximation Method. Optimality test: Modified Distribution Method (MODI), stepping stone method. Degeneracy in transportation problems. Assignment problem: formulation, Hungarian method for optimal assignment. Special cases: multiple optimal solutions, restrictions, and unbalanced assignment problems.	15

IV	**Game Theory and Decision-Making** Introduction to game theory: two-person zero-sum games. Maximin and Minimax principles. Games with pure strategies: saddle point. Games with mixed strategies: solution of 2×2 games using algebraic and graphical methods. Dominance principle for reducing the size of games. Introduction to decision-making under uncertainty: Maximin, Maximax, Laplace, Hurwicz, and Minimax Regret criteria.	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. H.A. Taha, Operation Research - An Introduction, Prentice Hall of India.
2. K. Swarup, P.K. Gupta and Manmohan, Operations Research, 13e, Sultan Chand & Sons.
3. P.K. Gupta and D.S. Hira, Operations Research, S. Chand & Co.
4. S.D. Sharma, Operation Research, Kedar Nath Ram Nath Publications.
5. I.K. Sharma, Mathematical Models in Operation Research, Tata McGraw Hill.

DEC-3 MATHEMATICAL MODELING

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	MATHEMATICAL MODELING
Course Code	M24-MAT-314
Course Type	DEC-3
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Differential Equations-I and II up to the 299 level

Course Objectives	A mathematical model is a description of a system (device or a phenomenon) using mathematical concepts and language. The process of developing a mathematical model is defined as mathematical modeling. A mathematical model may help to explain a system and to study the effects of different components, and to make predictions about the system. During this course, the students will learn basic concepts of mathematical modeling and to construct mathematical models for population dynamics, epidemic spreading, economics, medicine, arm-race, battle, genetics and other areas of physical/life/social sciences. The course also aims to let the students learn mathematical modeling through ordinary/partial differential equations and probability generating function.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the need/techniques/classification of mathematical modeling through the use of first order ODEs and their qualitative solutions through sketching. CLO 2: Learn to develop mathematical models using systems of ODEs to analyse/predict population growth, epidemic spreading for their significance in economics, medicine, arm-race or battle/war. CLO 3: Attain the skill to develop mathematical models involving linear ODEs of order two or more and difference equations, for their relevance in probability theory, economics, finance, population dynamics and genetics. CLO 4: Develop mathematical models through PDEs for mass-balance, variational principles, probability generating function, traffic flow problems alongwith relevant initial & boundary conditions.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Mathematical modeling: need, techniques, classification and illustrative examples; Mathematical modeling through ordinary differential equations of first order; qualitative solutions through sketching.	15
II	Mathematical modeling in population dynamics, epidemic spreading and compartment models; mathematical modeling through systems of ordinary differential equations; mathematical modeling in economics, medicine, arm-race, battle.	15
III	Mathematical modeling through ordinary differential equations of second order. Higher order (linear) models. Mathematical modeling through difference equations: Need, basic theory; mathematical modeling in probability theory, economics, finance, population dynamics and genetics.	15
IV	Mathematical modeling through partial differential equations: simple models, mass-balance equations, variational principles, probability generating function, traffic flow problems, initial & boundary conditions.	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Books

1. J.N. Kapur: Mathematical Modelling, New Age International Ltd.,(Third Edition) 2023.
2. M. Adler, An Introduction to Mathematical Modelling, HeavenForBooks.Com, 2001.
3. S.M. Moghadas, M.J.-Douraki, Mathematical Modelling: A Graduate Text Book, Wiley, 2018.
4. E.A. Bender, An Introduction to Mathematical Modeling, Dover Publication, 2000.
5. M. Adler, An Introduction to Mathematical Modelling, HeavenForBooks.Com, 2001.
6. S.M. Moghadas, M.J.-Douraki, Mathematical Modelling: A Graduate Text Book, Wiley, 2018.
7. E.A. Bender, An Introduction to Mathematical Modeling, Dover Publication, 2000.

PC-3 PRACTICAL-3

With effective from the Session: 2025-26

Part A - Introduction

Name of the Programme	M.Sc. Mathematics
Semester	III
Name of the Course	PRACTICAL-3
Course Code	M24-MAT-315
Course Type	PC-3
Level of the course	500-599
Pre-requisite for the course (if any)	
Course objectives	The objective of this laboratory course is to write codes for numerical methods and to execute those source programs using either of MATLAB/SCILAB/Octave platforms. In addition, hand on experience of using built-in functions, provided in the libraries of these platforms/software, for verification/ supplementing the source program should be realized. Also, some problem solving techniques based on papers M24-MAT-301 to M24-MAT-302 will be taught.
Course Learning Outcomes (CLO) After completing this course, the learner will be able to:	CLO 1: Understand the algorithms for solving listed mathematical problems and to solve practical problems related to core courses undertaken in the Semester-III from application point of view. CLO 2: Write source codes using either of MATLAB/SCILAB/Octave programming. CLO 3: Edit, compile/interpret and execute the source program for desired results. CLO 4: Verify/check results using built-in MATLAB/SCILAB/Octave functions.

	Theory	Practical	Total
Credits	0	4	4
Teaching Hours per week	0	8	8
Internal Assessment Marks	0	30	30
End Term Exam Marks	0	70	70
Max. Marks	0	100	100
Examination Time	0	4 hours	

Part B- Contents of the Course

Practicals	Contact Hours
Practical course will consist of two components Part-A and Part-B. The examiner will set 5 questions at the time of practical examination asking 2 questions from the Part-A and 3 questions from the Part-B by taking course learning outcomes (CLO) into consideration. The examinee will be required to solve one problem from the Part-A and to write and execute 2 questions from the Part-B.	120
Part-A Problems based on the theory courses MMATH21-301 to MMATH21-302 will be solved in this part and their record will be maintained in the Practical Note Book. Direct results and theorems will not be asked rather exercises or numerical problems or applied problems based on the theory parts will be done, as identified or given by the teacher concerned.	30
Part-B The following practicals will be done on the MATLAB/SCILAB/Octave platform and record of those will be maintained in the practical Note Book: 1. Solutions of simultaneous linear equations: Gauss-elimination method and Gauss-Jordan method. 2. Solutions of simultaneous linear equations using Jacobi method and Gauss-Seidel method. 3. Solution of algebraic / transcendental equations using Bisection method and Regula-falsi method. 4. Solution of algebraic / transcendental equations using Secant method and Newton-Raphson method. 5. Inversion of matrices using adjoints; Jordan method. 6. Numerical differentiation: using various differentiation formulas for error reduction. 7. Numerical integration using composite methods based on trapezoidal rule. 8. Numerical integration using composite Simpson1/3 rule and 3/8 rule. 9. Solution of ordinary differential equations Euler method and Modified Euler method. 10. Solution of ordinary differential equations using Runge-Kutta methods. 11. Statistical problems on central tendency (mean, mode, median) and dispersion (standard variation, standard error). 12. Least square method to fit polynomial (curve) of given degree to given data set. 13. Plotting of special functions.	90 (Lab hours include instructions for writing programs in MATLAB/ SCILAB and demonstration by a teacher and for run the programs on computer by students.)

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Practicum**	30	➢ **Practicum**	70
• Class Participation:	5	Lab record, Viva-Voce, write-up and execution of the programs	
• Seminar/Demonstration/Viva-voce/Lab records etc.:	10		
• Mid-Term Examination:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

1. S.R. Otto, J.P. Denier, An Introduction to Programming and Numerical Methods in MATLAB, Springer-Verlag, London, 2005.
2. William J. Palm III and William Palm, Introduction to MATLAB 7 for Engineers 2nd Edition, The McGraw-Hill Higher Education London, 2003.
3. Gupta R K, Numerical Methods: Fundamentals and Applications,Cambridge University Press 2019.

OEC Mathematical Tools For Other Disciplines

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	Mathematical Tools For Other Disciplines
Course Code	M24-OEC-331
Course Type	OEC
Level of the course	500-599
Pre-requisite for the course (if any)	

Course Objectives	The main objective of this course is to provide the students some of the mathematical tools with the help of which they can solve mathematical problems arising in their respective disciplines. Determinants and matrices will be helpful in finding solutions of systems of linear equations and the knowledge of differential equations will enable them to solve first and second order ordinary differential equations. This course also aims at introducing different popular numerical methods for solving transcendental and polynomial equations, system of linear equations, curve fitting, numerical differentiation, numerical integration. After successful completion of the course, a student will be able to draw the algorithm for the use of numerical methods in source programs of any programming language.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Know about the determinants, matrices, their properties and operations; attain the skill to find the rank of matrices, solve systems of linear equations and to find characteristic roots and characteristic vectors of a square matrix. CLO 2: Understand differential equations and attain skills to solve first and second order ordinary differential equations. CLO 3: Learn the use of numerical methods for solving transcendental and polynomial equations and direct methods for solving system of linear equations. Solve system of linear equations through iterative methods. CLO 4: Knowledge of using various interpolation methods for fitting polynomials to a data-set / function. Understand finite difference schemes/operators for numerical differentiation and attain ability to apply numerical methods for solving definite integrals.		
Credits	Theory	Practical	Total
	2	0	2
Teaching Hours per week	2	0	2
Internal Assessment Marks	15	0	15
End Term Exam Marks	35	0	35
Max. Marks	50	0	50
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: **The examiner will set 9 questions in all, selecting two questions from each unit and one compulsory question. The compulsory question (Question No. 1) will contain 4 parts, without any internal choice, covering the entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions carry equal marks. Use of non-programmable scientific calculator will be allowed in the examination.**

Unit	Topics	Contact Hours

I	Determinants and matrices: Basic properties and operations, elementary row operations, Rank of a matrix, Inverse of a matrix. Solution of system of linear homogeneous and non-homogeneous equations, consistency of linear systems of equations. Characteristic values and Characteristic vectors.	7
II	Differential equations: Equations of first order and first degree; variable separable, homogeneous, reducible to homogeneous, linear equation, exact differential equation, reducible to exact. Applications of differential equation. Solution of second order differential equation with constant coefficients.	7
III	Solution of Polynomial and Transcendental Equations: Bisection method, secant method, Regula-Falsi method, Newton-Raphson method. Solution of Systems of Linear Equations: Gauss elimination method, Gauss-Jordan method, Triangularization method. Iterative methods for Solving Systems of Linear Equations: Jacobi method, Gauss-Seidel iteration method.	8
IV	Curve fitting: Least-square approximation for fitting a straight line and polynomials of given degree. Numerical Differentiation: Methods based on Newton`s forward difference formula, Newton`s backward difference formula and central difference formulae (Sterling`s formula).  Numerical Integration: Trapezoidal rule, Simpson`s 1/3 rule, Simpson`s 3/8 rule, Newton-Cotes integration formula.	8
	Total Contact Hours	30

Suggested Evaluation Methods

Internal Assessment: 15		**End Term Examination: 35**	
➢ **Theory**	**15**	➢ **Theory:**	**35**
• Class Participation:	4	Written Examination	

• Seminar/presentation/assignment/quiz/class test etc.:	4	
• Mid-Term Exam:	7	

Part C-Learning Resources

Recommended Books/e-resources/LMS:

1. Seymour Lipschutz and Marc Lipson: Linear Algebra, Third Edition, McGraw Hill Education, 2005.
2. Shanti Narayan and P.K. Mittal: A text book of matrices, S. Chand & Company (Pvt) Ltd., 2018.
3. Sastry, S.S., Introductory Methods of Numerical Analysis, Fifth edition, PHI Learning, 2012.
4. Jain, M. K., Iyengar, S.R.K.| and Jain, R.K., Numerical Methods for Scientific and Engineering Computation, 6th Edition, New Age International Publishers, 2012.
5. Rajaraman, V., Computer Oriented Numerical Methods, Fourth edition, PHI learning, 2018.
6. Gourdin, A. and Boumahrat, M., Applied Numerical Methods, PHI Learning Private Ltd., 1996.

CC-13 PARTIAL DIFFERENTIAL EQUATIONS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	PARTIAL DIFFERENTIAL EQUATIONS
Course Code	M24-MAT-401
Course Type	CC-13
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	The learning objective of this paper is to study partial differential equations (PDE) which are used to describe a wide variety of phenomena such as sound, heat, electrostatics, electrodynamics, fluid dynamics, elasticity and mechanics. During this course, a student will learn about partial differential equations including definition, classifications, analytical theory and methods of solutions of IVP, transport equations, Laplace`s equation, Poisson`s equation and heat equations, Green`s function and method of solving PDEs by Green`s function approach. Other component of the learning objective is to study Wave equation, solutions of wave equation in different forms, Kirchhoff`s and Poisson`s formula, solution of non-homogeneous wave equation, solution of Laplace, heat and wave equations by method of separation of variables, similarity solutions and by using Fourier and Laplace transforms.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Classify the PDE of different orders into elliptic/ parabolic/ hyperbolic types and work on the methods to solve homogeneous and non-homogeneous elliptic equations. CLO 2: Understand the role of Green`s function in solving PDE and work on the methods/principle used to derive formulas for solutions of homogeneous and non-homogeneous parabolic/heat equations. CLO 3: Use various methods to solve the homogeneous and non-homogeneous wave equations, one to three dimensional, in different coordinate systems. Capacity to apply those techniques/methods to numerous problems that arise in science, engineering and other disciplines. CLO 4: Learn to solve non-linear first order PDEs through complete integrals, envelopes, characteristics and solve Laplace, heat and wave equations using method of separation of variables and using integral transforms.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Partial Differential Equations (PDE) of k^{th} order: Definition, examples and classifications. Initial value problems. Transport equations homogeneous and non-homogeneous, Radial solution of Laplace`s Equation: Fundamental solutions, harmonic functions and their properties, Mean value Formula.  Poisson`s equation and its solution, strong maximum principle, uniqueness, local estimates for harmonic functions, Liouville`s theorem, Harnack`s inequality. (Relevant portions from the recommended text books given at Sr. No. 1 & 2)	15

II	Green`s function and its derivation, representation formula using Green`s function, symmetry of Green`s function, Green`s function for a half space and for a unit ball. Energy methods: uniqueness, Drichlet`s principle.  Heat Equations: Physical interpretation, fundamental solution. Integral of fundamental solution, solution of initial value problem, Duhamel`s principle, non-homogeneous heat equation, Mean value formula for heat equation, strong maximum principle and uniqueness. Energy methods. (Relevant portions from the recommended text books given at Sr. No. 1 & 2)	15
III	Wave equation - Physical interpretation, solution for one dimentional wave equation, D`Alemberts formula and its applications, Reflection method, Solution by spherical means Euler-Poisson_Darboux equation Kirchhoff`s and Poisson`s formula (for n=2, 3 only). Solution of non –homogeneous wave equation for n=1,3. Energy method. Uniqueness of solution, finite propagation speed of wave equation. (Relevant portions from the recommended text books given at Sr. No. 1 & 2)	15
IV	Non-linear first order PDE- complete integrals, envelopes. Characteristics of (i) linear, (ii) quasilinear, (iii) fully non-linear first order partial differential equations. Hamilton Jacobi equations. Other ways to represent solutions: Method of Separation of variables for the Hamilton Jacobi equations, Laplace, heat and wave equations. Similarity solutions (plane waves, traveling waves, solitons, similarity under scaling). Fourier Transform, Laplace Transform, Convertible non-linear into linear PDE, Cole-Hop Transform, Potential functions, Hodograph and Legendre transforms. Lagrange and Charpit methods. (Relevant portions from the recommended text books given at Sr. No. 1 & 2)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources
Recommended Books/e-resources/LMS: **Recommended Text Books;** 1. L.C. Evans, *Partial Differential Equations*, Graduate Studies in Mathematics, American Mathematical Society, 2014. 2. Ian N. Sneddon, *Elements of Partial Differential Equations*, Dover Publications, 2006. **Reference Books:** 1. T. Amarnath, *An Elementary Course in Partial Differential Equations*, Jones & Bartlett Publishers, 2009. 2. P. Parsad and R. Ravindran, *Partial Differential Equations*, New Age / International Publishers, Third Edition, 2022. 3. John F. *Partial Differential Equations*, Springer-Verlag, New York, 4th Edition, 1982.

CC14 DISCRETE MATHEMATICS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	DISCRETE MATHEMATICS
Course Code	M24-MAT-402
Course Type	CC-14
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Abstract Algebra and Linear Algebra up to the 399 level

Course Objectives	The course consists of two sections. In the first section lattices are defined as algebraic structures. This section contains various types of lattices i.e. modular, distributive and complimented lattices. The notion of independent elements in modular lattices is introduced. Boolean algebra has been introduced as an algebraic system. Basic properties of finite Boolean algebra and application of Boolean algebra to switching circuit theory is also given. Section two contains graph theory. In this section students will be taught connected graphs, Euler's theorem on connected graphs, trees and their basic properties. This section also contains fundamental circuits and fundamental cut-sets, planner graphs, vector space associated with a graph, and the matrices associated with graphs, paths, circuits and cut-sets. The contents of this paper find many applications in computer science and engineering science.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concept of lattices, Boolean algebra. CLO 2: Apply lattices to switching circuits. CLO 3: Understand concept of graph, path, circuits, tree, fundamental circuits, cut-set and cut-vertices. CLO 4: Understand concept of planer and dual graph, circuit and cut-set subspace, fundamental circuit matrix, cut- set matrix, path matrix and adjacency matrix.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours

I	Properties of lattice, modular and distributive lattices. Boolean algebra, basic properties, Boolean polynomial, ideals, minimal forms of Boolean polynomials. (Chapter 1 of recommended text book, "Applied Abstract Algebra by Rudolf Lidl & Gunter Pilz")	15
II	Switching circuits, application of lattice to switching circuits, More Applications of Boolean Algebras. (Chapter 2 of recommended text book, "Applied Abstract Algebra by Rudolf Lidl & Gunter Pilz")	15
III	Finite and infinite graphs, Incidence and degree, Isolated vertex, pendant vertex, Null graph, isomorphism, subgraphs, walks, paths and circuits. Connected and disconnected graphs, Components of a graph, Euler graphs, Hamiltonian paths and circuit, the traveling salesman problem. Trees and their properties, pendant vertices in a tree, distance and centers in a tree, rooted and binary tree, Spanning tree, fundamental circuits. Spanning tree in a weighted graph. Cut-sets and their properties. Fundamental circuits and cut-sets. Connectivity and separability. (1.1 to 1.5, 2.1 to 2.10, 3.1 to 3.10, 4.1 to 4.6 of recommended text book, "Graph Theory with application to Engineering and Computer Science by Narsingh Deo")	15
IV	Planner graphs. Kuratowski's two graphs. Representation of planner graphs. Euler formula for planner graphs. Geometric dual, vector and vector spaces, Vector space associated with a graph. Basis vectors of a graph. Circuit and cut-set subspaces. Intersection and joins of W_C and	15

	W_S. Incidence matrix, submatrices of A(G), Circuit matrix, Fundamenta circuit matrix, and its rank, Cut-set matrix, path matrix and adjacency matrix. (5.1 to 5.6, 6.4 to 6.7, 6.9, 7.1 to 7.4, 7.6, 7.8 & 7.9 of recommended text book, "Graph Theory with application to Engineering and Computer Science by Narsingh Deo"))	
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. Rudolf Lidl & Gunter Pilz, Applied Abstract Algebra, Springer-Verlag, Second Edition, 1998.

2. Narsingh Deo, Graph Theory with application to Engineering and Computer Science, Courier Dover Publications, 2016.

Reference Books:

1. Nathan Jacobson: Lectures in Abstract Algebra Vol. I, Springer New York, 1976

2. L. R. Vermani and Shalini, A course in discrete Mathematical structures, Imperial College Press, London, 2012.

With effective from the Session: 2025-26			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	IV		
Name of the Course	ADVANCED COMPLEX ANALYSIS		
Course Code	M24-MAT-403		
Course Type	DEC-4		
Level of the course	500-599		
Pre-requisite for the course (if any)	Course on Complex Analysis		
Course Objectives	The main objective of this course is to understand the notion of logarithmically convex function, the spaces of continuous, analytic and meromorphic functions, theory of range of an entire function leading to Picard and related theorems.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the basics of logarithmically convex functions, learn about spaces of continuous, analytic and meromorphic functions. CLO 2: Be familiar with Weierstrass` factorization theorem, Gamma functions and its properties.  CLO 3: Know Mittag-Leffler`s theorem. Analytic continuation, Power series method of analytic continuation, Schwarz reflection principle. CLO 4: Know how big the range of an entire function is; prove Picard and related theorems.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Spaces of continuous functions, Spaces of analytic functions, Hurwitz`s theorem, Montel`s theorem, Spaces of meromorphic functions. Convex functions and Hadamard`s three circles theorem.	15
II	Weierstrass factorization theorem, Factorization of sine function, Gamma function and its properties, functional equation for gamma function, Reimann-zeta function, Riemann`s functional equation, Euler`s theorem.	15
III	Simply connected regions, Mittag-Leffler`s theorem. Analytic continuation, Power series method of analytic continuation, Schwarz reflection principle.	15
IV	Entire functions: Jensen`s formula, Poisson–Jensen formula. The genus and order of an entire function, Hadamard`s factorization theorem. The range of an analytic function: Bloch`s theorem, Little-Picard theorem, Schottky`s theorem, Montel-Carathedory theorem, Great Picard theorem.	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Book:

1. J. B.Conway, Functions of one complex variable, Narosa Publishing House, 2002.

Reference Books:

1. Ahlfors, L.V., Complex Analysis, Mc. Graw Hill Co., Indian Edition, 2017.

2. Churchill, R.V. and Brown, J.W., Complex Variables and Applications McGraw Hill Publishing Company, 1990.

3. Priestly, H.A., Introduction to Complex Analysis Claredon Press, Orford, 1990.

4. Liang-shin Hann & Bernard Epstein, Classical Complex Analysis, Jones and Bartlett Publishers International, London, 1996.

5. D.Sarason, Complex Function Theory, Hindustan Book Agency, Delhi, 1994.

6. Mark J.Ablewitz and A.S.Fokas, Complex Variables : Introduction & Applications, Cambridge University Press, South Asian Edition, 1998.

7. E.C.Titchmarsh, Theory of Functions, Oxford University Press, London, 1939.

8. S.Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.

9. D.C. Ullrich, Complex Made Simple, American Mathematical Society, 2008.

10. L. Hahn, B. Epstein, Classical Complex Analysis, Jones and Bartlett, 1996.

11. W. Rudin, Real and Complex Analysis, Third Edition, Tata McGraw-Hill, 2006.

DEC-4 ALGEBRAIC NUMBER THEORY

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	ALGEBRAIC NUMBER THEORY
Course Code	M24-MAT-404
Course Type	DEC-4
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Abstract Algebra and Field theory up to the 499 level

Course Objectives	The concept of Algebraic Number Theory is surely one of the recent ideas of mathematics. The main aim of this course is to introduce Norm and trace, Ideals in the ring of algebraic number field Fractional ideals, Chinese Remainder theorem, Different of an algebraic number field, Hurwitz constant, Ideal class group and Quadratic reciprocity.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concept of integral bases and discriminant of algebraic number field, ring of algebraic integers and ideal in the ring of algebraic integers. CLO 2: Learn about integrally closed domains, Dedekind domain, fractional ideals and unique factorization. CLO 3: Learn about Hurwitz`s lemma, Hurwitz constant, finiteness of the ideal class group, class number of an algebraic number field, Diophantine equations. CLO 4: Understand Legendre symbol, gauss sums, law of quadratic reciprocity, quadratic field.

	Theory	Practical	Total
Credits	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Norm and trace of algebraic numbers and algebraic integers, Bilinear map on algebraic number field K. Integral basis and discriminant of an algebraic number field, Index of an element of K, Ring O_k of algebraic integers of an algebraic number field K. Ideals in the ring of algebraic number field K.	15
II	Integrally closed domains. Dedekind domains. Fractional ideals of K Factorization of ideals as a product of prime ideals in the ring of algebraic integers of an algebraic number field K. G.C.D. and L.C.M. of ideals in O_k. Chinese Remainder theorem.	15

III	Euclidean rings. Hurwitz Lemma and Hurwitz constant. Equivalent fractional ideals. Ideal class group. Finiteness of the ideal class group. Class number of the algebraic number field K.	15
IV	Legendre Symbol, Jacobi symbol, Gauss sums, Law of quadratic reciprocity, Quadratic fields.	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. Jody Esmonde and M.Ram Murty, Problems in Algebraic Number Theory, Springer Verlag,(Second Edition), 2005.

Reference books:

1. Paulo Ribenboim: Algebraic Numbers, Wiley-Interscience, 1972.
2. R. Narasimhan and S. Raghavan: Algebraic Number Theory, Mathematical Pamphlets-4, Tata Institute of Fundamental Research, 1966.

DEC-4 GENERAL MEASURE AND INTEGRATION THEORY

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	GENERAL MEASURE AND INTEGRATION THEORY
Course Code	M24-MAT-405
Course Type	DEC-4
Level of the course	500-599
Pre-requisite for the course (if any)	Course on Measure and Integration
Course Objectives	The main objective of this course is to familiarize with general theory of measure and integration, in particular, with measurable functions, sequences of measurable functions, integrable functions, product measures, finite signed measures and integration over locally compact spaces.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand the concept of measure defined on a ring of sets, its properties; extension, uniqueness and completeness of measures; measurable spaces, measurable and simple functions. CLO 2: Have deep understanding of the concepts of convergence in measure, almost uniform convergence; apply the knowledge to prove Egoroff's theorem, Riesz-Weyl theorem, learn about integrable functions, indefinite integrals; demonstrate understanding of the statement and proof of the monotone convergence theorem. CLO 3: Understand the concepts of product measures; apply the knowledge to prove Fubini's theorem; understand signed measures; demonstrate understanding of the statement and proof of the Jordan-Hahn decomposition, Radon-Nikodym theorem. CLO 4: Know about the concepts of Baire sets, Baire measures, regularity of measures on locally compact spaces; apply the knowledge to prove Riesz-Markoff representation theorem related to the representation of a bounded linear functional on the space of continuous functions.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Measures, some properties of measures, outer measures, extension of measures, uniqueness of extension, completion of a measure, the LUB of an increasingly directed family of measures. (Scope as in the Sections 3-6, 9-10 of Chapter 1 of the book „Measure and Integration' by S.K. Berberian). Measurable spaces, measurable functions, combinations of measurable functions, limits of measurable functions, localization of measurability, simple functions (Scope as in Chapter 2 of the book „Measure and Integration' by S.K. Berberian).	15

II	Measure spaces, almost everywhere convergence, convergence in measure, almost uniform convergence, Egoroff`s theorem, Riesz-Weyl theorem (Scope as in Chapter 3 of the book „Measure and Integration` by S.K. Berberian). Integrable simple functions, non-negative integrable functions, integrable functions, indefinite integrals, the monotone convergence theorem, mean convergence (Scope as in Chapter 4 of the book „Measure and Integration` by S.K. Berberian)	15
III	Product Measures: Rectangles, Cartesian product of two measurable spaces, sections, the product of two finite measure spaces, the product of any two measure spaces, product of two σ- finite measure spaces, Fubini`s theorem. (Scope as in Chapter 6 (except section 42) of the book „Measure and Integration` by S.K. Berberian) Finite Signed Measures: Absolute continuity, finite singed measure, contractions of a finite signed measure, purely positive and purely negative sets, comparison of finite measures, Lebesgue decomposition theorem, a preliminary Radon-Nikodym theorem, Jordan-Hahn decomposition of a finite signed measure, domination of finite signed measures, the Radyon-Nikodym theorem for a finite measure space, the Radon-Nikodym theorem for a σ - finite measure space (Scope as in Chapter 7 (except Section 53) of the book „Measure and Integration` by	15

	S.K.Berberian).	
IV	Integration over locally compact spaces: continuous functions with compact support, G_δ's and F_σ's, Baire sets, Baire-sandwich theorem Baire measures, Borel sets, Regularity of Baire measures, Regular Borel measures, Integration of continuous functions with compact support Riesz-Markoff representation theorem (Scope as in relevant parts of the sections 54-57, 60, 62, 66 and 69 of Chapter 8 of the book „Measure and Integration` by S.K.Berberian)	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Text Book:

1. S.K. Berberian: Measure and Integration, American Mathematical Society, Reprint edition, 2011.

Reference Books:

1. H.L.Royden, Real Analysis (3rd Edition) Prentice-Hall of India, 2008.
2. G.de Barra, Measure theory and integration, New Age International,2014.
3. P.R.Halmos: Measure Theory, Springer New York, 2013.
4. I.K.Rana: An Introduction to Measure and Integration, Narosa Publishing House, Delhi, 1997.
5. R.G.Bartle: The Elements of Integration, John Wiley and Sons, Inc. New York, 1966.

DEC-4 ADVANCED FUZZY SET THEORY

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	ADVANCED FUZZY SET THEORY

Course Code	M24-MAT-406		
Course Type	DEC-4		
Level of the course	500-599		
Pre-requisite for the course (if any)			
Course Objectives	The course aims to provide students with a comprehensive understanding of Operations Research and fuzzy logic concepts. It focuses on developing the skills to identify and formulate optimization models, analyze queuing and inventory systems, and solve complex problems using techniques like linear programming, transportation, and game theory. Additionally, students will learn to apply fuzzy logic, fuzzy relations, and fuzzy sets in decision-making processes, particularly in environments characterized by uncertainty. The course also emphasizes the use of advanced mathematical tools and fuzzy measures to solve real-world problems, equipping students with the knowledge to make optimal decisions in diverse fields such as economics, business, and engineering.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Students will be able to define and analyze crisp and fuzzy relations, and apply fuzzy relation concepts to solve real-world problems. CLO 2: Students will develop a strong understanding of fuzzy equivalence relations, fuzzy compatibility relations, and their applications in decision-making and system design. CLO 3: Students will comprehend the concepts of possibility theory and necessity measures, and be able to apply possibility distribution functions in decision-making under uncertainty. CLO 4: Students will grasp the fundamentals of fuzzy logic, including its relation to classical logic and the application of multivalued logics, particularly in n-valued logic systems.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Fuzzy Relations: Crisp and fuzzy relations, projections and cylindrical extension, binary fuzzy relations, domain, range, and height of a fuzzy relation, membership matrices, sagittal diagram, inverse of a fuzzy relation, composition of fuzzy relations, standard composition, max-min composition, relational join, binary relations on a single set, directed graphs, reflexive, irreflexive, antireflexive, symmetric, asymmetric, antisymmetric, transitive (max-min transitive), non-transitive, antitransitive fuzzy relations.	15
II	Fuzzy equivalence relations, fuzzy compatibility relations, a compatibility class, maximal e-compatibles, complete a-cover, reflexive undirected graphs, fuzzy ordering relations, fuzzy upper bound, fuzzy preordering, fuzzy weak ordering, fuzzy strict ordering, fuzzy morphisms. Fuzzy measures, continuity from below and above, semicontinuous fuzzy measures, examples and simple properties; Evidence Theory, belief measure, superadditivity, monotonicity, plausibility measure, subadditivity, basic assignment, its relation with belief measure and plausibility measure, focal element of basic assignment, body of evidence, total ignorance, Dempster's rule of combination.	15
III	Possibility Theory, necessity measure, possibility measure, implications, possibility distribution function, lattice of possibility distributions, joint possibility distribution. Fuzzy sets and possibility theory, degree of possibility distribution. Fuzzy sets and possibility theory, degree of compatibility, degree of possibility, relation with possibility distribution function and possibility measure, example of possibility distribution for fuzzy proposition.	15

IV	Fuzzy Logic: An overview of classical logic, about logic functions of two variables, Multivalued logics, about three-valued logic, n-valued logic, degrees of truth, definition of primitives, fuzzy proposition, classification, canonical forms, relation with possibility distribution function, fuzzy quantifiers, their two kinds, relation with possibility distribution function, linguistic hedges, as a unary operation and modifiers, properties, inference from conditional fuzzy propositions, relations with characteristic and membership functions, compositional rule of inference, modus ponens and tollens, hypothetical syllogism.	15
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		

• Mid-Term Exam:	15

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Book:

1. 1. G. J. Klir and B. Yuan: Fuzzy Sets and Fuzzy: Logic Theory and Applications, Prentice Hall of India, 2008

Reference Books:

1. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer International Edition, 2005.

2. H.J. Zimmerman, Fuzzy Set Theory and its Applications, Allied Publishers Ltd., New Delhi, 1991.

3. John Yen, Reza Langari, Fuzzy Logic - Intelligence, Control and Information, Pearson Education, 1999.

4. A.K. Bhargava, Fuzzy Set Theory, Fuzzy Logic & their Applications, S. Chand & Company Pvt. Ltd., 2013.

DEC-5 WAVELET ANALYSIS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	WAVELET ANALYSIS
Course Code	M24-MAT-407
Course Type	DEC-5
Level of the course	500-599
Pre-requisite for the course (if any)	Course on Real Analysis
Course Objectives	Wavelet analysis is a modern supplement to classical Fourier analysis. In some cases Wavelet analysis is much better than Fourier analysis in the sense that fewer terms suffice to approximate certain functions. The main objective of this course is to familiarize with the standard features of Fourier transforms along with more recent developments such as the discrete and fast Fourier transforms and wavelets. We consider the idea of a multiresolution analysis and the course we follow is to go from MRA to wavelet bases.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Have an idea of the finite Fourier transform, convolution on the circle group T, the Fourier transform and residues and know about continuous analogue of Dini`s theorem and Lipschitz`s test. CLO 2: Know about (C,1) summability for integrals, understand the Fejer-Lebesgue inversion theorem, Parseval`s identities, the $L_2$ theory, Plancherel theorem and Mellin transform.  CLO 3: Have understanding of the Discrete and Fast Fourier transforms, and Buneman`s Algorithm. CLO 4: Understand Multiresolution Analysis, Mother wavelets; construction of scaling function with compact support, Shannon wavelets, Franklin wavelets, frames, splines and the continuous wavelet transform.
Credits	Theory: 4 / Practical: 0 / Total: 4

Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Fourier Transform: The finite Fourier transform, the circle group T, convolution to T, (L(T),+,*) as a Banach algebra, convolutions to products, convolution on T, the exponential form of Lebesgue's theorem, Fourier transform : trigonometric approach, exponential form, Basics/examples. Fourier transform and residues, residue theorem for the upper and lower half planes, the Abel kernel, the Fourier map, convolution on R, inversion, exponential form, inversion, trigonometric form, criterion for convergence, continuous analogue of Dini's theorem, continuous analogue of Lipschitz's test, analogue of Jordan's theorem. (Scope as in relevant parts of Chapter 5 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)	15
II	(C,1) summability for integrals, the Fejer-Lebesgue inversion theorem, the continuous Fejer Kernel, the Fourier map is not onto, a dominated inversion theorem, criterion for integrability of $\hat{f}$ Approximate identity for L_1 (R), Fourier Sine and Cosine transforms, Parseval's identities, the L_2 theory, Parseval's identities for L_2, inversion theorem for L_2 functions, the Plancherel theorem, A sampling theorem, the Mellin transform, variations. (Scope as in relevant parts of Chapter 5 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)	15
III	Discrete Fourier transform, the DFT in matrix form, inversion theorem for the DFT, DFT map as a linear bijection, Parseval's identities, cyclic convolution, Fast Fourier transform for N=2, Buneman's Algorithm, FFT for N=RC, FFT factor form. (Scope as in relevant parts of Chapter 6 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)	15

IV	Wavelets: orthonormal basis from one function, Multiresolution Analysis, Mother wavelets yield Wavelet bases, Haar wavelets, from	15

	MRA to Mother wavelet, Mother wavelet theorem, construction of scaling function with compact support, Shannon wavelets, Riesz basis and MRAs, Franklin wavelets, frames, splines, the continuous wavelet transform. (Scope as in relevant parts of Chapter 7 of the book "Fourier and Wavelet Analysis" by Bachman, Narici and Beckenstein)	
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Book:

1. G. Bachman, L. Narici and E. Beckenstein: Fourier and Wavelet Analysis, Springer, 2000

Reference Books:

1. Hernandez and G. Weiss: A first course on wavelets, CRC Press, New York, 1996
2. C. K. Chui: An introduction to Wavelets, Academic Press,1992
3. I. Daubechies: Ten lectures on wavelets, CBMS_NFS Regional Conferences in Applied Mathematics, 61, SIAM, 1992
4. V. Meyer, Wavelets, algorithms and applications SIAM, 1993
5. M.V. Wickerhauser: Adapted wavelet analysis from theory to software, Wellesley,MA, A.K. Peters, 1994
6. D. F. Walnut: An Introduction to Wavelet Analysis, Birkhauser, 2002
7. K. Ahmad and F.A. Shah: Introduction to Wavelets with Applications, World Education Publishers, 2013

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	ADVANCED FUNCTIONAL ANALYSIS
Course Code	M24-MAT-408
Course Type	DEC-5
Level of the course	500-599
Pre-requisite for the course (if any)	Course on Functional Analysis
Course Objectives	Spectral theory is one of the main branches of modern functional analysis and its applications. The main objective of this course is to familiarize with some advanced topics in functional analysis which include spectral theory of linear operators in normed spaces, compact linear operators on normed spaces and their spectrum, and spectral theory of bounded self-adjoint linear operators and unbounded linear operators in Hilbert spaces.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Undersatnd the spectrum of a bounded operator, spectral properties of bounded linear operators; apply the knowledge to prove spectral mapping theorem for polynomials; be familiar with Banach algebras and its properties. CLO 2: Learn about compact linear operators on normed spaces, their spectral properties and application to operator equations involving compact linear operators. CLO 3: Understand the spectral properties of bounded self-adjoint linear operators; apply the knowledge to prove spectral theorem for bounded self adjoint linear operators and extend the spectral theorem to continuous functions. CLO 4: Understand the basics of unbounded linear operators on Hilbert spaces; adjoints of unbounded linear operators; spectral properties of self-adjoint operators; multiplication and differentiation operators.

Credits	Theory	Practical	Total

	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Spectrum of a bounded operator: point spectrum, continuous spectrum and residual spectrum, spectral properties of bounded linear operators, the closedness and compactness of the spectrum of a bounded linear operator on a complex Banach space; further properties of resolvent and spectrum, spectral mapping theorem for polynomials. (Scope as in relevant parts of Sections 7.1 to 7.4 of Chapter 7 of „Introductory Functional Analysis with Applications` by E.Kreyszig) Non-emptiness of the spectrum of a bounded linear operator on a complex Banach space, spectral radius formula, Banach algebras, resolvent set and spectrum of a Banach algebra element, further properties of Banach algebras, spectral radius of a Banach algebra element, non-emptiness of the spectrum of a Banach algebra element. (Scope as in relevant parts of Sections 7.5 to 7.7 of Chapter 7 of „Introductory Functional Analysis with Applications` by E.Kreyszig)	15
II	Compact linear operators on normed spaces, compactness criterion, conditions under which the limit of a sequence of compact linear operators is compact, weak convergence and compact operators, separability of range, adjoint of compact operators, Spectral properties of compact linear operators on normed spaces, eigen values of compact linear operators, closedness of the range of T_λ, further spectral properties of compact linear operators. (Scope as in relevant parts of Sections 8.1 to 8.4 of Chapter 8 of „Introductory Functional Analysis with Applications` by E.Kreyszig) Operator equations involving compact linear operators, necessary and sufficient conditions for the solvability of various operator equations, further theorems of Fredholm type. Fredholm alternative. (Scope as in relevant parts of Sections 8.5 to 8.7 of Chapter 8 of „Introductory Functional Analysis with Applications` by E.Kreyszig)	15

III	Spectral theory of bounded self-adjoint linear operators: spectral properties of bounded self adjoint operators, positive operators projection operators and their properties. (Scope as in relevant parts of Sections 9.1 to 9.6 of Chapter 9 of „Introductory Functional Analysis with Applications` by E.Kreyszig) Spectral family of a bounded self adjoint linear operator, spectral representation of bounded self-adjoint linear operators, spectral theorem for bounded self-adjoint linear operators, extension of the spectral theorem to continuous functions, properties of the spectral family of a bounded self adjoint operator. (Scope as in relevant parts of Sections 9.7 to 9.11 of Chapter 9 of „Introductory Functional Analysis with Applications` by E.Kreyszig)	15
IV	Unbounded linear operators and their Hilbert adjoints, Hellinger-Toeplitz theorem, Hilbert-adjoint, symmetric and self-adjoint linear operators Closed linear operators and closures, spectral properties of self adjoint linear operators. (Scope as in relevant parts of Sections 10.1 to 10.4 of Chapter 10 of „Introductory Functional Analysis with Applications` by E.Kreyszig)  Spectral representation of unitary operators: Wecken`s lemma, spectral theorem for unitary operators, spectral representation for self-adjoint linear operators, multiplication and differentiation operators. (Scope as in relevant parts of Sections 10.5 to 10.7 of Chapter 10 of „Introductory Functional Analysis with Applications` by E.Kreyszig)	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		
Part C-Learning Resources			

Recommended Books/e-resources/LMS:

Recommended Text Book:

1. E.Kreyszig: Introductory Functional Analysis with Applications, Wiley India, 2007.

Reference Books:

1. G.F. Simmons: Introduction to Topology and Modern Analysis, McGraw Hill Book Co.,New York, 1983.

DEC-5 ADVANCED FLUID MECHANICS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	ADVANCED FLUID MECHANICS
Course Code	M24-MAT-409
Course Type	DEC-5
Level of the course	500-599
Pre-requisite for the course (if any)	Preliminary Course on Fluid Mechanics
Course Objectives	This course deals with mechanics of real (viscous) fluids and objective of this course is to let the students have deep understanding of gas dynamics, dynamics of viscous fluids and boundary layer theory. This is a strong foundation course to pursue research in the areas of Fluid Mechanics, Computational Fluid Dynamics, Bio-Mechanics, Mathematical Modeling and Mathematical Biology.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand wave motion, including sound, in a gas; Sonic, subsonic, supersonic, isentropic types of flows; shock waves and flow of gas through a nozzle. Capacity to solve simple gas flow problems. CLO 2: Have thorough knowledge of viscous fluids; stress, strain rate and relations between them and equations of motion for viscous fluids. CLO 3: Identify those viscous fluid flow problems whose exact solutions can be found and to learn the methods to solve such problems. Apply the knowledge to solve real world problems. CLO 4: Recognize concepts of dynamical similarity, dimensional analysis, Reynolds number, Wever Number, Mach Number, Froude Number, Eckert Number, Buckingham π-theorem and its applications. Understand the concept of boundary layer and the associated theory. Get exposure to real fluid flow problems of science and engineering.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Wave motion in a Gas. Speed of sound in a gas. Equation of motion of a Gas. Subsonic, sonic and supersonic flows. Isentropic gas flow, Flow through a nozzle. Shock waves. (Relevant portions from the recommended text book at Sr. No. 1)	15

II	Stress components in a real fluid. Relation between Cartesian components of stress. Translational motion of fluid element. Rate of strain quadric and principal stresses. Transformation of rates of strains. Stress analysis in fluid motion. Relations between stress and strain rate. The co-efficient of viscosity and laminar flow. Newtonian and non-Newtonian fluids. Navier-Stokes equations of motion. Equations of motion in cylindrical and spherical polar coordinates. (Relevant portions from the recommended text book at Sr. No. 1)	15
III	Dynamical similarity. Dimensional analysis. Buckingham π-theorem and its applications to viscous and compressible fluid flow. Reynolds number, Weber Number, Mach Number, Froude Number, Eckert Number. Prandtl boundary layer theory, Boundary layer thickness, Boundary layer equation in two-dimensions. The boundary layer flow over a flat plate (Blasius solution). Characteristic boundary layer parameters. Karman integral equations. Karman-Pohlhausen method. (Relevant portions from the recommended text book at Sr. No. 2)	15
IV	Two-dimensional flows: Use of cylindrical polar coordinates, Stream function, Some fundamental stream functions, Axisymmetric flow, Equations satisfied by Stokes`s stream function in irrotational flow, Basic Stokes`s stream functions, Boundary conditions satisfied by the stream function.	15

	Irrotational plane flows: Complex potential, Image systems in plane flows. Milne-Thomson circle theorem. Circular cylinder in uniform stream with circulation. Blasius theorem. (Relevant portions from the recommended text books at Sr. No. 1 & 2)		
	Total Contact Hours		60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. F. Chorlton, Text-book of Fluid Dynamics, CBS Publishers and Distributors Pvt. Ltd., 2018.
2. S. W. Yuan, Foundations of Fluid Mechanics, Prentice Hall of India Ltd., 1988.

Reference Books:

1. G.K. Batchelor, An Introduciton to Fluid Dynamics, Cambridge University Press, 2000.
2. A.J. Chorin and A. Marsden, A Mathematical Introduction to Fluid Dynamics, Springer-Verlag, New York, 1993.
3. L.D. Landau and E.M. Lifshitz, Fluid Mechanics, Pergamon Press, 1987.
4. H. Schlichting, Boundary Layer Theory, Springer, 2016.
5. A.D. Young, Boundary Layers, AIAA Education Series, Washington DC, 1989.
W.H. Besant and A.S. Ramsey, A Treatise on Hydromechanics, Part-II, CBS Publishers, Delhi, 2006.

2. R. Bhatia, Notes on Functional Analysis, TRIM series, Hindustan Book Agency, India, 2009.

3. J.E. Conway, A course in Operator Theory, Graduate Studies in Mathematics, Volume 21, AMS, 1999.

4. Martin Schechter, Principles of Functional Analysis, American Mathematical Society, 2004.

5. W. Rudin, Functional Analysis, TMH Edition, 1974.

DEC-5 ECONOMETRICS

With effective from the Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	ECONOMETRICS
Course Code	M24-MAT-410
Course Type	DEC-5
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	The course aims to provide students with the skills to evaluate economic theories using numerical methods, judge the validity of various economic theories, and extract useful information on economic policy issues from available data. It will equip students with the ability to understand and apply econometric models, focusing on linear regression techniques, hypothesis testing, and model interpretation. Additionally, the course will cover the concepts of multiple regression, violations of classical assumptions, and the application of econometric methods in real-world scenarios, enabling students to analyze and solve complex economic problems with rigor and precision.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Students will be able to understand the fundamentals of econometrics, including the nature of econometrics, the role of econometrics in model building, and the interpretation of regression models. CLO 2: Students will learn to estimate simple linear regression models using the method of ordinary least squares (OLS) and interpret the results. CLO 3: Students will understand and apply multiple linear regression models, including OLS estimation of parameters for multiple predictors. CLO 4: Students will learn to detect and understand the consequences of violations in classical assumptions, including multicollinearity, heteroscedasticity, and serial correlation.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Nature and scope of econometrics: objective behind building econometric models, nature of econometrics, model building, role of econometrics, interpretation of regression, nature and sources of data for econometric analysis, different measurement scales of variables.	15
II	Simple Linear Regression model: Two-variable case, estimation of the model by method of ordinary least squares, properties of estimators, goodness of fit, tests of hypotheses, scaling and units of measurements, Gauss-Markov theorem.	15

III	Multiple Linear Regression: OLS estimation of parameters, properties of OLS estimators, goodness of fit, regression coefficients and testing of hypotheses on parameters (individual and joint).	15
IV	Violations of Classical Assumptions: Multicollinearity concept, consequences, detection and remedies, heteroscedasticity and serial correlation concept & consequences, goodness of fit, partial regression coefficients and testing of hypotheses on parameters.	15

		Total Contact Hours	60
Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		
Part C-Learning Resources			

Recommended Books/e-resources/LMS:

Recommended Text Books;

1. D.N. Gujarati & S. Gunasekar, Basic Econometrics, 4e, McGraw-Hill, 2007.
2. G.S. Maddala & K. Lahiri, Introduction to Econometrics, 4e, John Wiley & Sons, 2008.
3. A. Koutsouyannis, Theory of Econometrics, 2e, Palgrave Macmillan Ltd, 2004.
4. J. Johnston, Econometrics Methods, 2e, McGraw-Hill International, 1997.

DEC-6 BIO-MATHEMATICS

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	BIO-MATHEMATICS
Course Code	M24-MAT-411
Course Type	DEC-6
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	This paper deals with a widely acceptable fact that many phenomena in life sciences and environment sciences can be modelled mathematically. Biology offers a rich variety of topics that are amenable to mathematical modeling, but some of the genuinely interesting are touched in this paper. It is assumed that students have no knowledge of biology, but they are expected to learn a substantial amount during the course. The ability to model problems using mathematics may not require much of the memorization, but it does require a deep understanding of basic principles and a wide range of mathematical techniques. Students are required to know differential equations and linear algebra. Topics in stochastic modeling are also touched, which requires some knowledge of probability.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Derive population growth laws/models regulated through logistic equation, involving species competition, Lotka-Volterra predator-prey equations to develop the theory of age-structured populations using both discrete- and continuous-time models for their applications in life cycle of a hermaphroditic worm. CLO 2: Model smaller populations those exhibit stochastic effects so as to analyze births rates in finite populations for their role in mathematical models of infectious disease epidemics and endemics so as to predict the future spread of a disease and to develop strategies for containment and eradication. CLO 3: Learn the mathematical modeling of the
	evolution/maintenance of polymorphism to understand population genetics, influence of natural selection, genetic drift, mutation, and migration (i.e., evolutionary forces) in changing the Allele frequencies. CLO 4: Derive mathematical models for biochemical reactions, including catalyzed by enzymes, based on the law of mass action, enzyme kinetics, fundamental enzymatic properties (i.e., competitive inhibition, allosteric inhibition, cooperativity) so as to know about DNA chemistry and the genetic code for alignment of DNA/RNA sequences by brute force, dynamic programming or gaps.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours

I	Population Dynamics: The Malthusian growth ; The Logistic equation; A model of species competition; The Lotka-Volterra predator-prey model; Age-structured Populations : Fibonacci`s rabbits; The golden ratio Φ; The Fibonacci numbers in a sunflower; Rabbits are an age-structured population; Discrete age-structured populations; Continuous age-structured populations; The brood size of a hermaphroditic worm.	15
II	Stochastic Population Growth : A stochastic model of population growth; Asymptotics of large initial populations; Derivation of the deterministic model; Derivation of the normal probability distribution; Simulation of population growth. Infectious Disease Modeling: The SI model; The SIS model; The SIR epidemic disease model; Vaccination ; The SIR endemic disease model ; Evolution of virulence.	15
III	Population Genetics: Haploid genetics; Spread of a favored allele; Mutation-selection balance ; Diploid genetics; Sexual reproduction;	15

	Spread of a favored allele; Mutation-selection balance; Heterosis; Frequency-dependent selection; Linkage equilibrium; Random genetic drift.	
IV	Biochemical Reactions: The law of mass action; Enzyme kinetics; Competitive inhibition; Allosteric inhibition; Cooperativity. Sequence Alignment: DNA ; Brute force alignment,dynamic programming approaches, handling of gaps, local alignment techniques, and commonly used alignment software tools.	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	30	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Books:

1. Mathematical Biology, Lecture notes for MATH 4333, (Jeffrey R. Chasnov)
2. Mathematical Biology I. An Introduction, Third Edition, 2002 (J.D. Murray)

DEC-6 STATISTICAL INFERENCE AND ESTIMATION

With effective from the Session: 2025- 26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	STATISTICAL INFERENCE AND ESTIMATION
Course Code	M24-MAT-412
Course Type	DEC-6
Level of the course	500-599
Pre-requisite for the course (if any)	

Course Objectives	This course aims to provide students with the theoretical foundation of statistical inference. It emphasizes the formulation and evaluation of statistical estimators, the construction of confidence intervals, hypothesis testing procedures, and both parametric and non-parametric inference. The course prepares students to apply logical and mathematical reasoning for analyzing real-world data.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand and derive point estimators using various estimation techniques. CLO 2: Construct and interpret confidence intervals for population parameters. CLO 3: Perform hypothesis testing using parametric methods. CLO 4: Apply Bayesian and non-parametric inference in data analysis.

Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	**Theory of Estimation** Concept of a statistical model and estimators. Properties of estimators unbiasedness, consistency, efficiency, and sufficiency. Methods of estimation: Method of Moments Maximum Likelihood Estimation (MLE),Least Squares Estimation. Rao-Blackwell theorem and Lehmann–Scheffe theorem. Cramér–Rao inequality and its applications Fisher information and exponential families of distributions.	15

II	**Confidence Intervals and Sampling Distributions** Concept of interval estimation and confidence level. Construction of confidence intervals for: Mean and variance (normal population),Proportions,Difference between means and variances Pivotal quantity method and use of MLE in interval estimation. Sampling distributions of sample mean, variance, and proportion. Use of t, χ^2, and F distributions in interval estimation.	15
III	**Hypothesis Testing (Parametric)** Statistical hypotheses: null and alternative hypotheses. Type I and Type II errors, power of a test, level of significance. Critical region, p-values, and test statistics. Most powerful tests and Uniformly Most Powerful (UMP) tests. Neyman–Pearson Lemma and its application. Likelihood Ratio Tests and their properties. Tests based on normal, t, χ^2, and F distributions.	15
IV	**Non-parametric and Bayesian Inference** Non-parametric tests: Sign test,Wilcoxon signed-rank test, Mann-Whitney U test, Kolmogorov–Smirnov one-sample and two-sample tests. Chi-square goodness-of-fit and test for independence. Bayesian estimation: Prior and posterior distributions, Bayes risk and Bayes estimators, Conjugate priors. Loss functions: quadratic and absolute error. Applications in small sample inference and decision-making.	15
	Total Contact Hours	60

Suggested Evaluation Methods			
Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	30	➢ **Theory:**	70
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:
Recommended Book:

2. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 2014.

Reference book:

1. R.V. Hogg, J.W. McKean and A.T. Craig, Introduction to Mathematical Statistics, Pearson, 2019.
2. R.J. Larsen and M.L. Marx, An Introduction to Mathematical Statistics and its Applications, Prentice Hall, 2012.

DEC-6 OPERATIONS RESEARCH

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	OPERATIONS RESEARCH
Course Code	M24-MAT-413
Course Type	DEC-6
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	This course aims to introduce students to advanced operations research techniques beyond linear programming. It focuses on integer programming, non-linear and dynamic programming, queuing models, simulation, and project management techniques. These tools are essential for solving complex decision-making problems in industry, logistics, service systems, and engineering.

Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Formulate and solve integer, goal, and non-linear programming problems. CLO 2: Understand and apply principles of dynamic programming to multistage decision problems. CLO 3: Analyze queuing systems and evaluate performance measures. CLO 4: Apply simulation and network models (PERT/CPM) for real-world planning and control.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

<u>Instructions for Paper- Setter:</u> The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	**Integer and Goal Programming** Introduction to integer programming problems: pure and mixed. Solution methods: Gomory's cutting plane method for single constraint problems.Branch and bound technique for mixed-integer programming. Concept of goal programming and its difference from LPP. Goal programming models: formulation and solution using weighted and lexicographic approaches. Real-world applications in finance, production, and scheduling.	15

II	**Non-linear and Dynamic Programming** Non-linear programming (NLP): Types of non-linear problems. Unconstrained optimization: methods of steepest descent, Newton-Raphson. Constrained optimization: Lagrange multipliers. Kuhn–Tucker conditions and their geometric interpretation. Quadratic programming: Wolfe's method. Dynamic programming: Bellman's principle of optimality. Multistage decision processes. Recursive equations and solution procedures. Applications in inventory control, resource allocation, and shortest path problems.	15
III	**Queuing Theory and Simulation** Components of a queuing system and operating characteristics. Poisson and exponential distributions in queuing models. Queuing models: M/M/1, M/M/c (finite and infinite capacity), Performance measures: average waiting time, queue length, system utilization. Birth-death process and steady-state probabilities. Introduction to simulation techniques. Monte Carlo simulation. Random number generation and validation. Simulation of queuing and inventory problems.	15
IV	**Network Models and Project Management (PERT/CPM)** Network representation of projects. Concepts: events, activities, critical path, float, slack time. PERT (Program Evaluation and Review Technique): Estimation of project duration using optimistic, pessimistic, and most likely times. Calculation of expected times and variances. CPM (Critical Path Method): Determination of critical path and project completion time. Crashing of projects and cost-time trade-off.	15

	the dual simplex algorithm, Initial solution for dual simplex algorithm. The dual simplex algorithm; an example, geometric interpretations of the dual linear programming problem and the dual simplex algorithm. A primal dual algorithm, Examples of the primal-dual algorithm. Transportation problem, properties of matrix A, the simplex method and transportation problem, simplification resulting from all $y_{ij}^{\alpha\beta} = \pm 1$ or 0, the transportation problem tableau, bases in the transportation tableau, the stepping stone algorithm, an example	
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. G. Hadley, Linear Programming, Narosa Publishing House, 2002.

Reference book:

1. S.I. Gass, Linear Programming: Methods and Applications, 5th Ed., Dover Publication Inc., 2011.
2. R.J. Vanderbei, Linear Programming: Foundations and Extensions: 196 (International Series in Operations Research & Management Science), Springer, 4th Edition, 2014.

DEC-6 NON-COMMUTATIVE RINGS

With effective from the Session: 2025-26	
Part A – Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	NON-COMMUTATIVE RINGS
Course Code	M24-MAT-414
Course Type	DEC-6
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Abstract Algebra up to the 499 level
Course Objectives	The course has been designed to give an exposure of the advanced ring theory. Course contains some special example of rings and Dedekind finite rings, simple and semi- simple modules, projective and injective modules. Nil radical and Jacobson radical of matrix rings are also part of the course. The course also contains sub-direct product of rings and commutativity theorems of Jacobson-Herstein and Herstein-Kaplansky. Finally theory of finite division rings is given.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand basic terminology and examples of non-commutative rings, simple and semi-simple modules and rings. Schur`s Lemma, Minimal ideals. CLO 2: Understand Jacobson radical of a ring R, Jacobson semi-simple rings, Hopkins-Levitzki Theorem. Jacobson radical of the matrix ring, Amitsur Theorem on radicals, Nakayama`s Lemma. CLO 3: Understand Prime and semi-prime ideals and rings. Lower and upper nil radical of a ring R. Amitsur theorem on nil radical of polynomial rings, Brauer`s Lemma, Structure theorem for left primitive rings. CLO 4: To learn about Subdirectly reducible and irreducible rings, Birchoff`s Theorem, G.Shin`s Theorem, Commutativity Theorems ,

	Division rings, Wedderburn's Little Theorem, Herstein's Lemma and theorem, Jacobson and Frobenius Theorem, Cartan-Brauer-Hua Theorem.		
Credits	Theory	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Basic terminology and examples of non-commutative rings i.e. Hurwitz's ring of integral quaternions, Free k-rings. Rings with generators and relations. Dedekind finite rings. Simple and semi-simple modules and rings. Spliting homomorphisms. Projective and Injective modules. Ideals of matrix ring $M_n(R)$. Structure of semi simple rings. Wedderburn-Artin Theorem Schur's Lemma. Minimal ideals.	15
II	Jacobson radical of a ring R.Annihilator ideal of an R-module M. Jacobson semi-simple rings. Nil and Nilpotent ideals. Hopkins-Levitzki Theorem. Jacobson radical of the matrix ring M_n (R). Amitsur Theorem on radicals. Nakayama's Lemma.	15
III	Prime and semi-prime ideals. m-systems. Prime and semi-prime rings. Lower and upper nil radical of a ring R Amitsur theorem on nil radical of polynomial rings. Brauer's Lemma. Levitzki theorem on nil radicals. Primitive and semi-primitive rings. Left and right primitive ideals of a ring R.	15
IV	Sub-direct products of rings. Subdirectly reducible and irreducible rings. Birchoff's Theorem. Reduced rings. G.Shin's Theorem.	15

	Commutativity Theorems of Jacobson, Jacobson-Herstein and Herstein Kaplansky. Division rings. Wedderburn's Little Theorem. Herstein's Lemma. Jacobson and Frobenius Theorem. Cartan-Brauer-Hua Theorem. Herstein's Theorem.	
	Total Contact Hours	60

Suggested Evaluation Methods

Internal Assessment: 30		End Term Examination: 70	
➢ **Theory**	**30**	➢ **Theory:**	**70**
• Class Participation:	5	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	10		
• Mid-Term Exam:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. T.Y. Lam : A First Course in Noncommutive Rings, Springer-Verlag, (Second Edition), 2001.

Reference book:

1. I.N. Herstein : Non-Commutative Rings carus monographs in Mathematics ,Vol.15., Math. Asso. of America, 1994.

PC-4 PRACTICAL-4

With effective from the Session: 2025-26			
Part A - Introduction			
Name of the Programme	M.Sc. Mathematics		
Semester	IV		
Name of the Course	PRACTICAL-4		
Course Code	M24-MAT-415		
Course Type	PC-4		
Level of the course	500-599		
Pre-requisite for the course (if any)			
Course objectives	The objective of this course is to make the students familiar with the R programming. This course also focuses on the statistical analysis of data structures using the programming and visualization features of R language. Also, some problem solving techniques based on papers M24-MAT-401 to M24-MAT-402 will be taught.		
Course Learning Outcomes (CLO) After completing this course, the learner will be able to:	CLO 1: Solve practical problems related to core courses undertaken in the Semester-IV from application point of view. CLO 2: Understand the basics of R programming language including data types, variables, operators, expressions, input/output statements, control structures and functions. CLO 3: Understand built in functions and tools of general use in R and know how to use those. CLO 4: Learn entering, plotting, manipulation and interpretation of data using statistical functions of R.		
Credits	Theory	Practical	Total
	0	4	4
Teaching Hours per week	0	8	8
Internal Assessment Marks	0	30	30

End Term Exam Marks	0	70	70
Max. Marks	0	100	100
Examination Time	0	4 hours	

<table>
<tr><th colspan="2">Part B- Contents of the Course</th></tr>
<tr><th>Practicals</th><th>Contact Hours</th></tr>
<tr><td>Practical course will consist of two components Part-A and Part-B. The examiner will set 5 questions at the time of practical examination asking 2 questions from the Part-A and 3 questions from the Part-B by taking course learning outcomes (CLO) into consideration. The examinee will be required to solve one problem from the Part-A and to write and execute 2 questions from the Part-B.</td><td>120</td></tr>
<tr><td>Part-A

Problems based on the theory courses M24-MAT-401 to M24-MAT-402 will be solved in this part and their record will be maintained in the Practical Note Book. Direct results and theorems will not be asked rather exercises or numerical problems or applied problems based on the theory parts will be done, as identified or given by the teacher concerned.</td><td>30</td></tr>
<tr><td>Part-B

The following practicals will be done on the R platform/software package and record of those will be maintained in the practical Note Book:

1. Starting R, entering data, storing data as a vector
2. Entering data into R;
i. Using c
ii. Using scan
iii. Using scan with file
iv. Editing your data
v. Reading in tables of data
vi. Spreadsheet data
3. Practical examples illustrating templates of functions, for loops and conditional expressions in R.
4. Find mean, variance and standard deviation using R functions.
5. Practical examples with univariate data:
i. Categorical data; Using tables, factors, bar chart, pie chart
ii. Numerical data; measures of center and spread
iii. Stems and leaf charts, histograms, boxplots, frequency polygons using R functions
6. Comparison of bivariate data with plots.
7. Program to fit linear regression line.
8. Program to find Spearman`s rank correlation coefficient.
9. Practical examples of plotting graphs using points, abline, lines, plot and curve R functions.
10. Practical examples of storing, accessing and manipulating multivariate data in data frames.</td><td>90

(Lab hours include instructions for writing programs in R platform/software package and demonstration by a teacher and for run the programs on computer by students.)</td></tr>
</table>

11. Generate random numbers using uniform, normal, binomial, exponential distributions.

12. To estimate confidence interval using p-test.
13. To estimate confidence interval using t-test.
14. To estimate confidence interval using z-test.
15. Hypothesis testing by mean and median.

Suggested Evaluation Methods

Internal Assessment: 30		**End Term Examination: 70**	
➢ **Practicum**	**30**	➢ **Practicum**	70
• Class Participation:	5	Lab record, Viva-Voce, write-up and execution of the programs	
• Seminar/Demonstration/Viva-voce/Lab records etc.:	10		
• Mid-Term Examination:	15		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

1. John Verzani, Using R for Introductory Statistics, Chapman and Hall/CRC, 2014.
2. John Verzani, simple R-Using R for Introductory Statistics, lecture notes in pdf format, open source.

EEC EMPLOYABILITY SKILLS IN MATHEMATICS

With effective from the Session: 2025-26			
Part A – Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	IV		
Name of the Course	EMPLOYABILITY SKILLS IN MATHEMATICS		
Course Code	M24-MAT-416		
Course Type	EEC		
Level of the course	500-599		
Pre-requisite for the course (if any)			
Course Objectives	The main aim of this course is to introduce essential mathematics for Data Science. This course will impart the mathematical skills for analyzing the large data and enhancing the employment potential of Master student of Mathematics.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concepts of different probability distributions for discrete variables and their implementation in R. CLO 2: Understand concepts of different probability distributions for continuous variables and their implementation in R. CLO 3: Learn about consistency and sufficiency of Estimators, Method of Moments, Basic Concepts of Confidence Interval Estimation and to attain skills to implement these techniques in R. CLO 4: Have understanding of basics of Tests of Hypothesis and Decision Rules, Test Procedures, Sample Test for Mean with Known and Unknown Variances, Test of Hypothesis for Variance in hypothesis testing with one sample and two sample test.		
Credits	Theory	Practical	Total
	2	0	2
Teaching Hours per week	2	0	2
Internal Assessment Marks	15	0	15
End Term Exam Marks	35	0	35
Max. Marks	50	0	50
Examination Time	3 hours		

Part B- Contents of the Course

Instructions for Paper- Setter: The examiner will set 9 questions asking two questions from each unit and one compulsory question by taking course learning outcomes (CLOs) into consideration. The compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question.

All questions will carry equal marks.

Unit	Topics	Contact Hours
I	Computation of Probability using R. Basics of Probability Distributions for Discrete Variables: Discrete Uniform Distribution in R, Binomial Distribution in R, Poisson Distribution in R, Geometric Distribution in R.	8
II	Basics of Probability Distributions for Continuous Random Variables: Normal Distribution in R, Bivariate Probability Distribution in R Software, Covariance and Correlation- Examples and R Software, Chi square Distribution, t- Distribution, F- Distribution, Distribution of Sample Mean, Convergence in Probability and Weak Law of Large Numbers.	7
III	Consistency and Sufficiency of Estimators, Method of Moments, Method of Maximum Likelihood and Rao Blackwell Theorem, Basic Concepts of Confidence Interval Estimation, Confidence Interval for Mean in One Sample with Known Variance, Confidence Interval for Mean and Variance.	8
IV	Basics of Tests of Hypothesis and Decision Rules, Test Procedures for One Sample Test for Mean with Known Variance, One Sample Test for Mean with Unknown Variance, Two Sample Test for Mean with Known and Unknown Variances, Test of Hypothesis for Variance in One and Two Samples.	7
	Total Contact Hours	30

Suggested Evaluation Methods

Internal Assessment: 15		**End Term Examination: 35**	
➢ **Theory**	15	➢ **Theory:**	35
• Class Participation:	4	Written Examination	
• Seminar/presentation/assignment/quiz/class test etc.:	4		
• Mid-Term Exam:	7		

Part C-Learning Resources

Recommended Books/e-resources/LMS:

Recommended Book:

1. John Verzani, Using R for Introductory Statistics, Chapman and Hall/CRC, 2014.
2. John Verzani, simple R-Using R for Introductory Statistics, lecture notes in pdf format, open source.
3. Heumann, Christian, Schomaker, Michael, Shalabh, Introduction to Statistics and Data Analysis With Exercises, Solutions and Applications in R, Springer 2016.
4. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, George C. Runger, 2018, Wiley (Low price edition available)
5. Probability and Statistics for Engineers. Richard A. Johnson, Irwin Miller, John Freund
6. Mathematical Statistics with Applications. Irwin Miller, Marylees Miller, Pearson Education

7. The R Software-Fundamentals of Programming and Statistical Analysis -Pierre Lafaye de Micheaux, Rémy Drouilhet, Benoit Liquet, Springer 2013
8. A Beginner's Guide to R (Use R) By Alain F. Zuur, Elena N. Ieno, Erik H.W.G. Meesters, Springer 2009