CC-11 M24-MAT-301 FLUID MECHANICS

With effective from the Session: Scheme; 2024-25 , Syllabus; 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	FLUID MECHANICS
Course Code	M24-MAT-301
Course Type	CC-11
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

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	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.

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	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	15

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	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)	
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.

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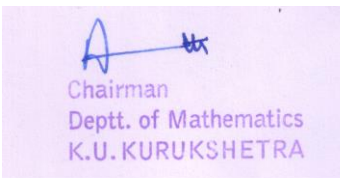
Session: 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	FUNCTIONAL ANALYSIS
Course Code	M24-MAT-302
Course Type	CC-12
Level of the course	500-599
Pre-requisite for the course (if any)	Courses on Algebra and Real Analysis
Course Objectives	The main 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, along with classifying operators into self-adjoint, unitary and normal operators.
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; convergence of operators by using a suitable norm; apply the knowledge to compute the dual spaces. 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]; know about adjoint of operators; understand reflexivity of a space and demonstrate understanding of the statement and proof of uniform boundedness theorem. CLO 3: Know about the notions of strong and weak convergence; understand open mapping theorem, bounded inverse theorem and closed graph theorem; 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; classify operators into self-adjoint, unitary and normal 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

<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	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, integral operator, bounded linear extension, bounded linear functionals, normed spaces of operators, dual spaces with examples. (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], adjoint operator, norm of the adjoint operator. Reflexive spaces, uniform boundedness theorem and some of its applications to the space of polynomials and Fourier series. (Scope as in relevant parts of sections 4.1 to 4.7 of Chapter 4 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)	15
III	Strong and weak convergence, open mapping theorem, bounded inverse theorem, closed linear operators, closed graph theorem. (Scope as in relevant parts of sections 4.8, 4.12 and 4.13 of Chapter 4 of 'Introductory Functional Analysis with Applications' by E.Kreyszig)	15

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	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)	
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. Hilbert-adjoint operator, its existence and uniqueness, properties of Hilbert-adjoint operators, self-adjoint, unitary and normal operators. (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,

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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.

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Session: 2025-26			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	III		
Name of the Course	ADVANCED TOPOLOGY		
Course Code	M24-MAT-303		
Course Type	DEC-1		
Level of the course	500-599		
Pre-requisite for the course (if any)	Course on Topology		
Course Objectives	The main objective of this course is to familiarize with some advanced topics in topology. We start with introduction of filters. Having discussed the convergence of sequences in topological spaces and in first axiom topological spaces, we move on to the introduction and convergence of nets in topological spaces followed by canonical way of converting nets to filters and vice versa. The concepts of metrisable spaces and paracompactness also form a part of the course along with some topics from algebraic topology including homotopy of paths and the fundamental group of the circle.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Know about filters and compactness in topological spaces and apply the knowledge to prove specified theorems. CLO 2: Know about nets in topological spaces; learn canonical way of converting nets to filters and vice versa. CLO 3: Have understanding of metrisable spaces and Urysohn's metrisation theorem; know about locally finite family and its equivalent forms, paracompactness of a metrisable space; apply knowledge to prove Nagata-Smirnov metrisation theorem and Smirnov metrisation theorem. CLO 4: Know about homotopy of paths, the fundamental group, covering spaces and the fundamental group of the circle. Retractions and fixed points.		
Credits	Theory	Practical	Total
	4	0	4

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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	Definition and examples of filters on a set, finer filter, ultra filter (u.f.) and its characterizations, Ultra Filter Principle (UFP). image of a filter under a function. convergence of filters: limit point (cluster point) and limit of a filter and relationship between them, Continuity in terms of convergence of filters. Hausdorffness and filter convergence. Compactness: Definition and examples of compact spaces, compactness in terms of finite intersection property (f.i.p.), continuity and compact sets, compactness and separation properties. regularity and normality of a compact Hausdorff space. compactness and filter convergence, Tychonoff product theorem. (Scope as in relevant portions of Chapters 2 & 5 of Kelley's book recommended at Sr. No.1).	15
II	Convergence of sequences in topological spaces and in first axiom topological spaces, Nets in topological spaces, convergence of nets, Hausdorffness and convergence of nets, Subnets and cluster points, sequences and subsequences, canonical way of converting nets to filters and vice versa, their convergence relations. Compactness and convergence of nets, monotone nets, universal nets, convergence classes, proof of the fact that every class is actually derived from a topology. (Scope as in relevant portions of Chapter 2 of Kelley's book recommended at Sr. No.1)	15
III	Definition and examples of metrisable spaces, Urysohn's metrisation theorem. Locally finite family, its equivalent forms, countably locally finite family, refinement, open refinement, closed refinement of a family, existence of countably locally finite open covering of a metrisable space, Nagata-Smirnov metrisation theorem, Paracompactness, normality of a paracompact Hausdorff space, paracompactness of a metrisable space and of regular Lindelof space, Smirnov metrisation theorem. (Scope as in theorems 34.1, 39.1-39.2. 40.3, 41.1-41.5 and 42.1 of Chapter 6 of the	15

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	book by 'Munkres' recommended at Sr. No. 2)	
IV	Homotopy of paths: Path homotopy, straight-line homotopy, product operation on paths, operation * on path-homotopy classes induced by the product operation on paths, groupoid properties of *. The fundamental group. Covering spaces, The fundamental group of the circle. Retractions and fixed points. (Scope as in Sections 51-55 of Chapter 9 of the book by 'Munkres' recommended at Sr. No. 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 Book:

1 J.L.Kelley, General Topology, Springer Verlag, New York, 2012.

2. J.R.Munkres, Topology, Pearson Education Asia, 2002.

Reference Books:

1. K. Chandrasekhara Rao, Topology, Narosa Publishing House Delhi,2009.

2. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.

3. A.H.Wallace, Introduction to Algebraic Topology, Dover Publications, 2007

4. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 2006.

5. C.W.Patty, Foundation of Topology, Jones & Bertlett, 2009.

6. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1983.

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DEC-1 M24-MAT-304 COMMUTATIVE ALGEBRA

With effective from the Session: Scheme; 2024-25 , Syllabus; 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, tensor product modules, localisation, primary decomposition of an ideal. This course also contains Integrally closed domains, Noether's normalization theorem, chain conditions on rings and modules, primary decomposition of an ideal in Notherian rings. Structure theorem of Artinian rings.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Learn about free modules, projective modules, tensor products and flat modules. CLO 2: Learn about ideals, local rings, localisation and applications. CLO 3: Understand Noetherian modules, primary decomposition, Artinian modules and length of a module. 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	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.

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Unit	Topics	Contact Hours
I	Free module, submodules, cyclic modules, homomorphism of R-modules, rank of Module. exact sequence, projective modules, Shanuel's lemma, tensor products, finitely generated R-algebra, flat modules.	15
II	Ideals, maximal ideals, prime ideals, nilpotent elements, nil radical, Jacobson radical of R, comaximal, Chinese remainder theorem, extension and contraction of ideal, local rings, Nakayama lemma, localisation and quotients, localisation of localisation, applications, patching up of localisations.	15
III	Noetherian modules, Hilbert's basis theorem, primary ideal, primary decomposition. first and second uniqueness theorem, Artinian modules, structure of Artinian rings, composition series of R-module, Jordan Holder theorem, length of a module.	15
IV	Integral elements, integral closure, integral extensions, lying above, going up theorem, integrally closed domains, going-down theorem, finiteness of integral closure, Noether's normalisation theorem, weak nullstellensatz, Hilbert's nullstellensatz.	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.

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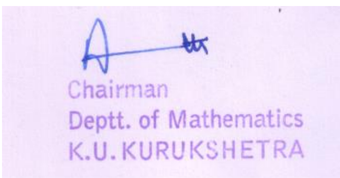
DEC-1 M24-MAT-305 Differential Geometry

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 $\boldsymbol{r}_{11}, \boldsymbol{r}_{12}, \boldsymbol{r}_{22}$, 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

Suggested Evaluation Methods

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.

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DEC-1 M24-MAT-306 ELASTICITY

With effective from the Session: Scheme; 2024-25 , Syllabus; 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

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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

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K.U. KURUKSHETRA

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.

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DEC-2 M24-MAT-307 ADVANCED NUMERICAL ANALYSIS

With effective from the Session: Scheme; 2024-25 , Syllabus; 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

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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, Moore-Penrose inverse method, 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, Rutishauser 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, Euler-Maclaurin's formula, Romberg Integration, Double integration. **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, Predictor-Corrector methods; Adams-Bashforth methods, Adams-	15

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	Moulton formula, Milne-Simpson method, System of Differential Equations. Finite difference method for solving second order IVPs and BVPs, Shooting method for boundary value problems.	
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 , solving hyperbolic equations using method of characteristics, explicit and implicit methods, Lax-Wendroff's 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. Pal, M., *Numerical Analysis for Scientists and Engineers*, Narosa Publishing House Pvt. Ltd., 2008.
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.

Reference books;

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

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Session: 2025-26			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	III		
Name of the Course	FUZZY SETS AND APPLICATIONS		
Course Code	M24-MAT-308		
Course Type	DEC-2		
Level of the course	500-599		
Pre-requisite for the course (if any)			
Course Objectives	Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling; and are facilitators for common-sense reasoning in decision making in the absence of complete and precise information. The main objective of this course is to familiarize the students with fuzzy sets, operations on fuzzy sets, fuzzy numbers, fuzzy relations, possibility theory and fuzzy logic.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Learn about fuzzy sets; understand fuzzy-set-related notions such as α level sets, convexity, normality, support, etc., their properties and various operations on fuzzy sets. CLO 2: Understand the concepts of t-norms, t-conforms, fuzzy numbers; extend standard arithmetic operations on real numbers to fuzzy numbers. CLO 3: Understand various type of fuzzy relations. CLO 4: Apply fuzzy set theory to possibility theory and Fuzzy logic.		
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			

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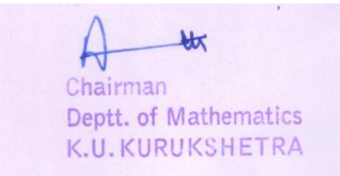
<table>
<tr><td colspan="3">compulsory question (Question No. 1) will consist 7 parts covering entire syllabus. The examinee will be required to attempt 5 questions, selecting one question from each unit and the compulsory question. All questions will carry equal marks.</td></tr>
<tr><th>Unit</th><th>Topics</th><th>Contact Hours</th></tr>
<tr><td>I</td><td>Fuzzy Sets: α -cuts, strong α -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, fuzzy set inclusion, scalar cardinality of a fuzzy set, the degree of subsethood (Scope as in relevant parts of sections 1.3-1.4 of Chapter 1 of the book by Klir & Yuan).

Additional properties of α cuts, Representation of fuzzy sets, three basic decomposition theorems of fuzzy sets, Extension principle for fuzzy sets, proof of the fact that the extension principle is strong cutworthy but not cutworthy (Scope as in relevant parts of Chapter 2 of the book by Klir & Yuan)

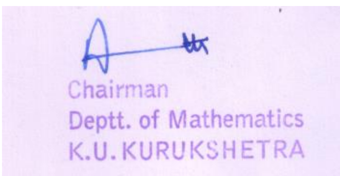
Operations on fuzzy sets: types of operations, fuzzy complements, equilibrium of a fuzzy complement, equilibrium of a continuous fuzzy complement, first and second characterization theorems of fuzzy complements (Scope as in relevant parts of sections 3.1 and 3.2 of Chapter 3 of the book by Klir & Yuan).</td><td>15</td></tr>
<tr><td>II</td><td>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, convertion 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), combination of operations, aggregation operations (Scope as in relevant parts of sections 3.3 to 3.6 of Chapter 3 of the book by Klir & Yuan).

Fuzzy numbers, relation between fuzzy number 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 operations on fuzzy numbers, extension of standard arithmetic operations on real numbers to fuzzy numbers, lattice of fuzzy numbers, (R, MIN, MAX) as a distributive lattice, fuzzy equations, equation A+X = B, equation A.X = B (Scope as in relevant</td><td>15</td></tr>
</table>



	parts of Chapter 4 of the book by Klir & Yuan)	
III	Fuzzy Relations: Crisp and fuzzy relations, projections and cylindrical extensions, 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. Fuzzy equivalence relations, fuzzy compatibility relations, α -compatibility class, maximal α -compatibles, complete α -cover, reflexive undirected graphs, fuzzy ordering relations, fuzzy upper bound, fuzzy pre ordering, fuzzy weak ordering, fuzzy strict ordering, fuzzy morphisms. Sup-i compositions of Fuzzy relations, Inf-i compositions of Fuzzy relations. (Scope as in the relevant parts of Chapter 5 of the book by Klir & Yuan)	15
IV	Possibility Theory : 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, examples; Possibility Theory, necessity measure, possibility measure, implications, possibility distribution function, lattice of possibility distributions, joint possibility distribution. Fuzzy sets and possibility theory, Possibility theory versus probability theory (Scope as in the relevant parts of Chapter 7 of the book by Klir & Yuan) Fuzzy Logic: An overview of classical logic, about logic functions of two variables, Multivalued logics, Fuzzy propositions, Fuzzy Quantifiers, Linguistic Hedges, Inference from conditional fuzzy propositions, inference from conditional and qualified propositions, inference from unqualified propositions. (Scope as in the relevant parts of Chapter 8 of the book by Klir & Yuan)	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.

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DEC-2 M24-MAT-309 Mathematical Statistics

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	Mathematical statistics is very useful in all branches of science as well as all branches of social sciences. The concept of mathematical statistics is surely one of the popular branch of applied mathematics. The main aim of this course is to introduce descriptive measures, probability, random distribution, probability models, mathematical expectation, correlation coefficient, discrete probability distributions, continuous probability distributions, sampling probability distributions, stochastic convergence, stochastic independence, statistical inference. An attempt has been made in this course to strike a balance between the different concepts of mathematical statistics.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand descriptive measures, probability, random variables and distribution functions. CLO 2: Understand mathematical expectation, generating functions, law of large numbers, correlation and regression. CLO 3: Learn about discrete probability distributions, continuous probability distributions and sampling distributions. CLO 4: Learn about large sample theory and statistical inference.		
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			

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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 of central tendency, measures of dispersion, measures of skewness, measures of Kurtosis. Probability-Basic terminology, addition theorem of probability, Boole's inequality, conditional probability, Multiplication theorem of probability, independent events. Bayes' theorem. Distribution function, discrete random variable, continuous random variable, two dimensional random variable, transformation of one dimensional random variable, transformation of two dimensional random variable.	15
II	Mathematical expectation, expectation of random variable, expectation of function of random variable, properties of expectation and variance , Covariance, Cauchy-schwarz inequality, Jenson inequality, moment generating function, cumulants, characteristic function, Chebychev's Inequality, convergence in probability, weak law of large numbers, scatter diagram, karl pearson's coefficients of Correlation, Linear regression.	15
III	Discrete probability distributions-uniform distributions, Bernoulli distributions, Binomial distributions, Poisson distributions. Continuous probability distribution- Normal distributions, rectangular distributions, triangular distributions, Gamma distributions. Central limit theorem. Sampling distributions- chi square distribution, Student's 't' distribution, F distribution, relation between t and F , relation between F and chi-square.	15
IV	Large sample theory- types of sampling, parameter and statistic, test of significance, procedure for testing of hypothesis. Statistical inference- characteristic of estimators, Cramer-Rao inequality, MVU, Rao-Blackwell 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

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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.

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DEC-2 M24-MAT-310 NUMBER THEORY

With effective from the Session: Scheme; 2024-25 , Syllabus; 2025-26			
Part A – Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	III		
Name of the Course	NUMBER THEORY		
Course Code	M24-MAT-310		
Course Type	DEC-2		
Level of the course	500-599		
Pre-requisite for the course (if any)	Courses on Algebra and Number theory up to the 199 level		
Course Objectives	The concept of number theory is surely one of the oldest ideas of Mathematics. The main aim of this course is to introduce arithmetic functions, Diophantine equations, Farey sequences, geometry of numbers, continued fractions. An attempt has been made in this course to strike a balance between different concepts of number theory.		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand concept of greatest integer function, arithmetic function, mobius inversion formula, recurrence function, combinatorial number theory . CLO 2: Find solution of Diophantine equations and rational points on curve. CLO 3: Understand concept of Farey fractions, irrational numbers and geometry of numbers. CLO 4: Have deep understanding of simple continued fractions, approximation to irrational number, Pell's equation.		
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**

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I	Greatest integer function, Arithmetic function, multiplicative function, completely multiplicative function, mobius- inversion formula, recurrence function, combinational number theory.	15
II	Solution of the equation ax+by =c, simultaneous linear equations, Unimodular matrices, Pythagorean triangles, some assorted examples, ternary quadratic forms, rational points on curves.	15
III	Farey sequences, rational approximations, Hurwitz theorem, irrational numbers, Blichfeldt's principle, Minkowski's Convex body theorem, Lagrange's four square theorem.	15
IV	Euclidean algorithm, finite and infinite continued fractions, approximations to irrational numbers, Best possible approximations, Hurwitz theorem, Periodic continued fractions, Pell's equation.	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. Ivan Niven, Herbert S. Zuckerman , Hugh L. Montgomery, An Introduction to the Theory of Numbers, John Wiley & Sons (Fifth Edition), 1991.
2. G.H. Hardy and E.M. Wright, An introduction to the theory of numbers, Oxford University Press, 6th Ed, 2008.

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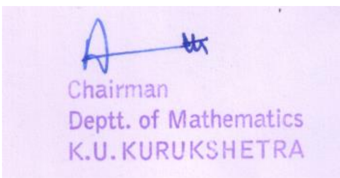
DEC-3 M24-MAT-311 ALGEBRAIC CODING THEORY

With effective from the Session: Scheme; 2024-25 , Syllabus; 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.		
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	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.

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DEC-3 M24-MAT-312 Financial Mathematics

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

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	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

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Deptt. of Mathematics
K.U. KURUKSHETRA

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

DEC-3 M24-MAT-313 INTEGRAL EQUATIONS

With effective from the Session: Scheme; 2024-25, Syllabus; 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	III
Name of the Course	INTEGRAL EQUATIONS
Course Code	M24-MAT-313
Course Type	DEC-3
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: Learn the use of numerical methods for finding an eigenvalue and the analytical methods to solve the singular integral equations from Cauchy-type to Hilbert-type, which involve Cauchy's principal value, closed/open contours and the Riemann-

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	Hilbert problem.		
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	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

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K.U. KURUKSHETRA

	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	The Abel Integral Equation. Inversion formula for singular integral equation with Kernel of the type h(s)-h(t), $0<\alpha<1$, Cauchy's principal value for integrals solution of the Cauchy-type singular integral equation, closed contour, unclosed contours and the Riemann-Hilbert problem. The Hilbert-Kernel, solution of the Hilbert-Type singular Intergal equation. (Chapter 8 of the book Ram P. Kanwal, *Linear Integral Equations: Theory & Techniques*).	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.

DEC-3 M24-MAT-314 MATHEMATICAL MODELING

With effective from the Session: Scheme; 2024-25 , Syllabus; 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-

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K.U. KURUKSHETRA

	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:

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Recommended Book

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.

PC-3 M24-MAT-315 PRACTICAL-3

<table>
<tr><td colspan="4">With effective from the Session: Scheme; 2024-25 , Syllabus; 2025-26</td></tr>
<tr><td colspan="4" align="center">Part A - Introduction</td></tr>
<tr><td>Name of the Programme</td><td colspan="3">M.Sc. Mathematics</td></tr>
<tr><td>Semester</td><td colspan="3">III</td></tr>
<tr><td>Name of the Course</td><td colspan="3">PRACTICAL-3</td></tr>
<tr><td>Course Code</td><td colspan="3">M24-MAT-315</td></tr>
<tr><td>Course Type</td><td colspan="3">PC-3</td></tr>
<tr><td>Level of the course</td><td colspan="3">500-599</td></tr>
<tr><td>Pre-requisite for the course (if any)</td><td colspan="3"></td></tr>
<tr><td>Course objectives</td><td colspan="3">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.</td></tr>
<tr><td>Course Learning Outcomes (CLO)
After completing this course, the learner will be able to:</td><td colspan="3">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.</td></tr>
<tr><td></td><td colspan="3"></td></tr>
<tr><td rowspan="2">Credits</td><td>Theory</td><td>Practical</td><td>Total</td></tr>
<tr><td>0</td><td>4</td><td>4</td></tr>
</table>

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K.U. KURUKSHETRA

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.)

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Deptt. of Mathematics
K.U. KURUKSHETRA

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.

CC-13 M24-MAT-401 PARTIAL DIFFERENTIAL EQUATIONS

With effective from the Session: Scheme; 2024-25, Syllabus; 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,

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	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

<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	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	15

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	& 2)	
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		

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K.U. KURUKSHETRA

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, 4^{th} Edition, 1982.

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K.U. KURUKSHETRA

CC-14 M24-MAT-402 MECHANICS AND CALCULUS OF VARIATIONS

With effective from the Session: Scheme; 2024-25, Syllabus; 2025-26

Part A - Introduction

Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	MECHANICS AND CALCULUS OF VARIATIONS
Course Code	M24-MAT-402
Course Type	CC-14
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	Analytical mechanics deals with motion of a system as a whole not as individual particles and takes in to account the constraints of the system to solve problems. This course let the students to understand basic concepts of analytical mechanics, calculus of variations, degrees of freedom, generalized coordinates, Lagrangian mechanics, Hamiltonian mechanics, principles of least action and Hamilton-Jacobi theory.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Understand moments and products of inertia, kinetic energy of a rigid rotating body, Laws of conservation of momentum, angular momentum and energy. Demonstrate knowledge to solve related problems of mechanics. CLO 2: Learn about three-dimensional rigid body dynamics and generalized coordinates. CLO 3: Understand Lagrange's equation for potential forces, Variational principles, Hamiltonian, Canonical transformations and Hamilton Jacobi equation. 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	0	30
End Term Exam Marks	70	0	70

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

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	Moments and products of inertia, The theorems of parallel and perpendicular axes, Angular momentum of a rigid body about a fixed point and about fixed axes, Principal axes. Kinetic energy of a rigid body rotating about a fixed point, Momental ellipsoid – equimomental system, Coplanar distributions, General motion of a rigid body. Problems illustrating the laws of motion, Problems illustrating the law of conservation of angular momentum, Problems illustrating the law of conservation of energy, Problems illustrating impulsive motion. (Relevant portions from the book 'Textbook of Dynamics' by F. Chorlton).	15
II	Euler's dynamical equations for the motion of a rigid body about a fixed point, Further properties of rigid motion under no forces, Some problems on general three-dimensional rigid body motion, The rotating earth. Note on dynamical systems, Preliminary notions, Generalized coordinates and velocities, Virtual work and generalized forces, Derivation of Lagrange's equations for a holonomic system, Case of conservative forces, Generalized components of momentum and impulse. Lagranges equations for impulsive forces, Kinetic energy as a quadratic function of velocities. Equilibrium configurations for conservative holonomic dynamical systems, Theory of small oscillations of conservative holonomic dynamical systems. (Relevant portions from the book 'Textbook of Dynamics' by F. Chorlton).	15
III	Lagrange's equations for potential forces, Variational principles in Mechanics: Hamilton's principle, The principle of least action. Hamiltonian and canonical equations of Hamilton. Basic integral invariant of Mechanics. Canonical transformations, Hamilton Jacobi equation.	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	(Relevant portions from the text book recommended at Sr. No. 2).	
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. 3 & 4).	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 Dynamics* 2nd Ed, CBS, 2002.
2. F. Gantmacher, *Lectures in Analytical Mechanics*, Mir Publishers, 1975.
3. Francis B. Hilderbrand, *Methods of Applied Mathematics*, Courier Corporation, 2012.
4. A.S. Gupta, *Calculus of Variations with Applications*, PHI Learning Pvt. Ltd., 1996.

Reference Books:

1. H. Goldstein, C.P. Poole and J.L. Safko, *Classical Mechanics* (3rd edition), Pearson, 2011.
2. I.M. Gelfand and S.V. Fomin, *Calculus of Variations*, Dover Publications, 2012.
3. S.K. Sinha, *Classical Mechanics*, Alpha Science International Limited, 2009.
4. Louis N. Hand and Janet D. Finch, Analytical Mechanics, Cambridge University Press, 2008.

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K.U. KURUKSHETRA

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 and its fusion with maximum modulus theorem, the spaces of continuous, analytic and meromorphic functions, Runge's theorem and topics related with it, introduce harmonic function theory leading to Dirichlet's problem, 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 that helps in extending maximum modulus theorem; learn about spaces of continuous, analytic and meromorphic functions. CLO 2: Be familiar with Riemann mapping theorem, Weierstrass' factorization theorem, Gamma functions and its properties. CLO 3: Understand Runge's theorem; know harmonic function theory on a disk; apply the knowledge in solving Dirichlet's problem; know about Green's function. 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		

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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	Convex functions and Hadamard's three circles theorem, Phragmen-Lindelöf theorem. Spaces of continuous functions, Arzela-Ascoli theorem, Spaces of analytic functions, Hurwitz's theorem, Montel's theorem, Spaces of meromorphic functions.	15
II	Riemann mapping theorem, Weierstrass' factorization theorem, Factorization of sine function, Gamma function and its properties, functional equation for gamma function, Bohr-Mollerup theorem, Reimann-zeta function, Riemann's functional equation, Euler's theorem.	15
III	Runge's theorem, Simply connected regions, Mittag-Leffler's theorem. Analytic continuation, Power series method of analytic continuation, Schwarz reflection principle. Monodromy theorem and its consequences.	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

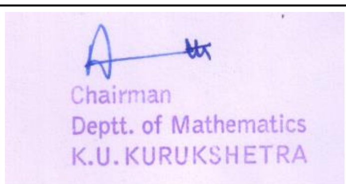
Recommended Books/e-resources/LMS:

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.

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DEC-4 M24-MAT-404 ALGEBRAIC NUMBER THEORY

With effective from the Session: Scheme; 2024-25 , Syllabus; 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, Dedekind domains, Fractional ideals, Chinese Remainder theorem, Different of an algebraic number field, Hurwitz constant, Ideal class group, Minkowski's bound 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 , different of an algebraic number field, Dedekind theorem CLO 3: Learn about Hurwitz's lemma, Hurwitz constant, finiteness of the ideal class group, class number of an algebraic number field, Diophantine equations, minkowski's bound CLO 4: Understand Legendre symbol, gauss sums, law of quadratic reciprocity, quadratic field, primes in special progression, class number of quadratic fields		
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			

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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, order of ideal in prime ideal, ramification degree of prime ideals, different of an algebraic number field K, Dedekind 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. Diophantine equations, Minkowski's bound.	15
IV	Legendre Symbol, Jacobi symbol, Gauss sums, Law of quadratic reciprocity, Quadratic fields, Primes in special progression, class number of 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:

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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.

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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

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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	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

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	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.

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DEC-4 M24-MAT-406 MATHEMATICAL ASPECTS OF SEISMOLOGY

With effective from the Session: Scheme; 2024-25 , Syllabus; 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	MATHEMATICAL ASPECTS OF SEISMOLOGY
Course Code	M24-MAT-406
Course Type	DEC-4
Level of the course	500-599
Pre-requisite for the course (if any)	
Course Objectives	Seismology is the study of earthquakes and deals with the generation and propagation of seismic waves. This course has been designed to study applications of mathematics in the field of seismology and will first introduce about the interior of the Earth and basic concepts related to earthquakes viz. causes, observation and location of earthquakes, magnitude and energy etc. The students will learn the mathematical representation of waves, solutions of wave equation in different forms and wave phenomena in detail; elastic waves, their reflection and refraction; mathematical models for the propagation of surface waves and source problems.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO1. Understand introductory concepts of earthquakes, seismology and wave propagation so as to form a strong foundation to learn the subject. Know mathematical representation of progressive waves and wave characteristics. Have knowledge to solve wave equation in different coordinate systems. CLO 2. Learn representation of spherical waves and their expansion in terms of plane waves. Learn techniques to solve wave equation in order to obtain Kirchoff, Poisson and Helmholtz formulae which find great importance in energy transport phenomenon in science and engineering. Have deep understanding of elastic waves. CLO 3. Learn about seismic waves and understand reflection and refraction of seismic waves and surface waves. Apply knowledge of mathematics and knowledge attained in first two COs to formulate mathematical models having application in seismology and to solve such problems.

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	CLO 4. Understand seismic sources (area, line and point). Attain skills to formulate and solve Lamb's problems. Attain knowledge and mathematical tools to pursue research in the area of seismology and to contribute to the science and society.		
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	Introduction to Seismology: Earthquakes, Causes of earthquakes; Elastic rebound theory, Location of earthquakes, Strength of earthquakes; Earthquake magnitude and intensity, Observation of earthquakes; Seismograms, Seismometers, Earthquake Focal Mechanisms, Energy released by earthquakes, Seismic waves as probes of Earth's interior, Interior of the earth. General form of progressive waves, Harmonic waves, Plane waves, Wave equation. Principle of superposition, Stationary waves. Special types of solutions: Progressive and Stationary type solutions of wave equation in Cartesian cylindrical and spherical coordinate systems. D'Alembert's formula. Inhomogeneous wave equation. Group velocity, Relation between phase velocity and group velocity. (Relevant articles from the book "*Waves*" by Coulson & Jeffrey)	15
II	Spherical waves. Expansion of a spherical wave into plane waves: Sommerfield's integral. Kirchoff's solution of the wave equation, Poissons's formula, Helmholtz's formula. (Relevant articles from the book "*Mathematical Aspects of Seismology*" by M. Bath) The elastic wave equation for a homogeneous isotropic medium, Vector wave equation: Vector solutions, Vector Helmholtz equation, Elastic	15

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	wave equation without body forces, *P-*, *SV-*, *and SH*-wave displacements, Polarization of particle motion, Flux of energy in harmonic waves. (Relevant articles from the book "Elastic Wave Propagation and Generation in Seismology" by Jose Pujol)	
III	Snell's law of reflection and refraction. Ray parameter and slowness. Reflection of plane P and SV waves at a free surface. Partition of reflected energy. Reflection at critical angles. Reflection and reflection of plane P, SV and SH waves at an interface. Special cases of Liquid-Liquid interface, Liquid-Solid interface and Solid-Solid interface. Surface waves: Rayleigh waves, Love waves and Stoneley waves. (Relevant articles from the book, "*Elastic waves in Layered Media*" by Ewing et al).	15
IV	Two dimensional Lamb's problems in an isotropic elastic solid: Area sources and Line Sources in an unlimited elastic solid. A normal force acts on the surface of a semi-infinite elastic solid, tangential forces acting on the surface of a semi-infinite elastic solid. Three dimensional Lamb's problems in an isotropic elastic solid: Area sources and Point sources in an unlimited elastic solid, Area source and Point source on the surface of semi-infinite elastic solid. (Relevant articles from the book "*Mathematical Aspects of Seismology*" by Markus Bäth) The scalar wave equation with a source term; Impulsive sources, arbitrary sources. Lam*é*'s solution of the elastic wave equation. The elastic wave equation with a concentrated force in a direction. (Relevant articles from the book "Elastic Wave Propagation and Generation in Seismology" by Jose Pujol)	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

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

1. C.A. Coulson and A. Jeffrey, Waves: A mathematical approach to the common types of wave motion, Longman Higher Education, 1977, Published online by Cambridge University Press, 2016.
2. M. Bath, *Mathematical Aspects of Seismology*, Elsevier Publishing Company, 1968.
3. W.M. Ewing, W.S. Jardetsky and F. Press, *Elastic Waves in Layered Media*, McGraw Hill Book Company, 1957.

Reference Books:

1. P.M. Shearer, Introduction to Seismology, Cambridge University Press,(UK) 1999.
2. Jose Pujol, Elastic Wave Propagation and Generation in Seismology, Cambridge Universty Press, 2003.
3. Seth Stein and Michael Wysession, An Introduction to Seismology, Earthquakes and Earth Structure, Blackwell Publishing Ltd., 2003.
4. Aki, K. and P.G. Richards, Quantitative Seismology: theory and methods, W.H. Freeman, 1980.
5. Bullen, K.E. and B.A. Bolt, *An Introduction to the Theory of Seismology*, Cambridge Universty Press, 1985.
6. C.M.R. Fowler, *The Solid Earth*, Cambridge University Press, 1990.

Chairman
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K.U. KURUKSHETRA

DEC-5 M24-MAT-407 ADVANCED DISCRETE MATHEMATICS

With effective from the Session: Scheme; 2024-25, Syllabus; 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	ADVANCED DISCRETE MATHEMATICS
Course Code	M24-MAT-407
Course Type	DEC-5
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.

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K.U. KURUKSHETRA

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, a puzzle with multicolored cubes, 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. Network flows. (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

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	W_S. Incidence matrix, submatrices of A(G), Circuit matrix, Fundamental 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.

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<table>
<tr><th colspan="4">Session: 2025-26</th></tr>
<tr><th colspan="4">Part A - Introduction</th></tr>
<tr><td>Name of Programme</td><td colspan="3">M.Sc. Mathematics</td></tr>
<tr><td>Semester</td><td colspan="3">IV</td></tr>
<tr><td>Name of the Course</td><td colspan="3">ADVANCED FUNCTIONAL ANALYSIS</td></tr>
<tr><td>Course Code</td><td colspan="3">M24-MAT-408</td></tr>
<tr><td>Course Type</td><td colspan="3">DEC-5</td></tr>
<tr><td>Level of the course</td><td colspan="3">500-599</td></tr>
<tr><td>Pre-requisite for the course (if any)</td><td colspan="3">Course on Functional Analysis</td></tr>
<tr><td>Course Objectives</td><td colspan="3">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.</td></tr>
<tr><td>Course Learning Outcomes (CLOs)
After completing this course, the learner will be able to:</td><td colspan="3">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.</td></tr>
<tr><td rowspan="2">Credits</td><td>Theory</td><td>Practical</td><td>Total</td></tr>
<tr><td>4</td><td>0</td><td>4</td></tr>
</table>

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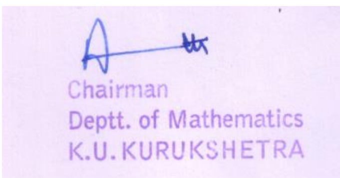
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30
End Term Exam Marks	70	0	70
Max. Marks	100	0	100
Examination Time	3 hours		

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	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, 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	15



	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)	
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.

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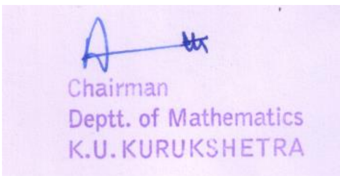
2. R. Bhatia, Notes on Functional Analysis, TRIM series, Hindustan Book Agency, India, 2009.

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 M24-MAT-409 ADVANCED FLUID MECHANICS

With effective from the Session: Scheme; 2024-25 , Syllabus; 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.

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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

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K.U. KURUKSHETRA

	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.

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DEC-5 M24-MAT-410 BOUNDARY VALUE PROBLEMS

With effective from the Session: Scheme; 2024-25, Syllabus; 2025-26	
Part A - Introduction	
Name of Programme	M.Sc. Mathematics
Semester	IV
Name of the Course	BOUNDARY VALUE PROBLEMS
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 objective of this course is to learn to solve the boundary value problems. Boundary value problems find applications in all area of science and engineering. The different techniques to solve boundary value problems and mixed boundary value problems are studied in this course. Such problems can be solved with Green's function approach, Integral transform methods and by using Perturbation techniques. One of the objectives to study this course is to expose a student to real world problems that are formulated as boundary value problems.
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Reduce boundary value problems involving ODEs to the equivalent integral and to solve such problems with Green's function and Modified Green's function approaches. Apply these techniques in problem solving. CLO 2: Learn to find solutions of boundary value problems involving Laplace's equation, Poisson's equation and Helmoltz's equation by using theory of integral equations and Green's function. Attain skill to solve such BVP which arise frequently in different branches of engineering and sciences. CLO 3: Learn to solve the integral equations by integral transform methods. Apply the gained knowledge in solving mixed boundary problems. CLO 4: Understand Perturbation methods and attain capability to apply perturbation techniques in solving different listed boundary value problems of Electrostatics, Hydrodynamics and Elasticity.

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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	Applications to Ordinary Differential Equations; Initial value problems, Boundary Value Problems. Dirac Delta functions. Green's function approach to reduce boundary value problems of a self-adjoint-differential equation with homogeneous boundary conditions to integral equation forms. Green's function for N^{th}-order ordinary differential equation. Modified Green's function. (Chapter 5 of the book "Linear Integral Equations, Theory and Techniques by R. P. Kanwal").	15
II	Applications to partial differential equations: Integral representation formulas for the solution of the Laplace and Poisson Equations. The Newtonian, single-layer and double-layer potentials, Interior and Exterior Dirichlet problems, Interior and Exterior Neumann problems. Green's function for Laplace's equation in a free space as well as in a space bounded by a ground vessel. Integral equation formulation of boundary value problems for Laplace's equation. Poisson's Integral formula. Green's function for the space bounded by grounded two parallel plates or an infinite circular cylinder. The Helmholtz equation. (Chapter 6 of the book "Linear Integral Equations, Theory and Techniques by R. P. Kanwal").	15
III	Integral Transform methods: Introduction, Fourier transform. Laplace transform. Convolution Integral. Application to Volterra Integral Equations with convolution-type Kernels. Hilbert transform. Applications to mixed Boundary Value Problems: Two-part Boundary Value problems, Three-part-Boundary Value Problems, Generalized Three-part Boundary Value problems. (Chapter 9 & 10 of the book "Linear Integral Equations, Theory and Techniques by R. P. Kanwal").	15

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IV	Integral equation perturbation methods: Basic procedure, Applications to Electrostatics, Low-Reynolds-Number Hydrodynamics: Steady stokes Flow, Boundary effects on Stokes flow, Longitudinal oscillations of solids in stokes Flow, Steady Rotary Stokes Flow, Rotary Oscillations in Stokes Flow, Rotary Oscillation in Stokes Flow, Oseen Flow-Translation Motion, Oseen Flow-Rotary motion Elasticity, Boundary effects, Rotation, Torsion and Rotary Oscillation problems in elasticity, crack problems in elasticity, Theory of Diffraction. (Chapter 11 of the book "Linear Integral Equations, Theory and Techniques by R. P. Kanwal").	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.

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DEC-6 M24-MAT-411 BIO-MATHEMATICS

With effective from the Session: Scheme; 2024-25 , Syllabus; 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

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	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

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	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; Gaps; Local alignments; Software.	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)

Session: 2025-26			
Part A - Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	IV		
Name of the Course	FOURIER AND WAVELET ANALYSIS		
Course Code	M24-MAT-412		
Course Type	DEC-6		
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	Practical	Total
	4	0	4
Teaching Hours per week	4	0	4
Internal Assessment Marks	30	0	30

Chairman
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K.U. KURUKSHETRA

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

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	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		

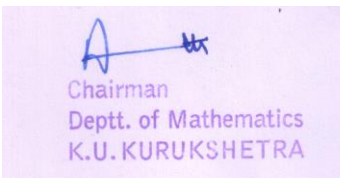
Part C-Learning Resources

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

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

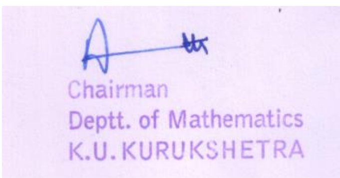
Reference Books:

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



DEC-6 M24-MAT-413 Linear Programming

Session: 2025-26			
Part A – Introduction			
Name of Programme	M.Sc. Mathematics		
Semester	IV		
Name of the Course	Linear Programming		
Course Code	M24-MAT-413		
Course Type	DEC-6		
Level of the course	500-599		
Pre-requisite for the course (if any)			
Course Objectives	Real life systems can have dozens or hundreds of variables, or more, which may not be handled through standard algebraic techniques. Such systems are used every day in the organization and allocation of resources and are generally handled through linear programming based on "optimization techniques". Linear programming deals with the problems of maximizing or minimizing a linear function subject to linear constraints in the form of equalities or inequalities. The general process for solving linear-programming exercises is to graph the constraints to form a walled-off area called "feasibility region". Then, corners of this feasibility region are tested to find the highest (or lowest) value of the outcome (or resources).		
Course Learning Outcomes (CLOs) After completing this course, the learner will be able to:	CLO 1: Learn background for linear programming, theory of simplex method, detailed development and computational aspects of the simplex method. CLO 2: Understand simplex method in detail, resolution of the degeneracy problem and obtain skills to apply these techniques. CLO 3: Learn revised simplex method and its real life applications. CLO 4: Understand duality theory and its ramifications, transportation problem.		
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	Simultaneous linear equations, Basic solutions, Linear transformations, Point sets, Lines and hyperplanes, Convex sets, Convex sets and hyperplanes, Convex cones, Restatement of the LP problem, Slack and surplus variables, Preliminary remarks on the theory of the simplex method, Reduction of any feasible solution to a basic feasible solution, Definitions and notations regarding LP problems. Improving a basic feasible solution, Unbounded solutions, Optimality conditions, Alternative optima, Extreme points and basic feasible solutions. The simplex method, Selection of the vector to enter the basis, Degeneracy and breaking ties, Further development of the transformation formulas, The initial basic feasible solution, artificial variables, Inconsistency and redundancy, Tableau format for simplex computations, Use of the tableau format, Conversion of a minimization problem to a maximization problem, Review of the simplex method.	15
II	The two-phase method for artificial variables, Phase I, Phase II, Numerical examples of the two-phase method, Requirements space, Solutions space, Determination of all optimal solutions, Unrestricted variables, Charnes' perturbation method regarding the resolution of the degeneracy problem. Selection of the vector to be removed, Definition of b(€). Order of vectors in b(€), Use of perturbation technique with simplex tableau format, Geometrical interpretation of the perturbation method. The generalized linear programming problem, The generalized simplex method, Examples pertaining to degeneracy, An example of cycling.	15
III	Revised simplex method: Standard Form I, Computational procedure for Standard Form I, Revised simplex method: Standard Form II, Computational procedure for Standard Form II, Initial identity matrix for Phase I, Comparison of the simplex and revised simplex methods, The product form of the inverse of a non-singular matrix.	15
IV	Alternative formulations of linear programming problems, Dual linear programming problems, Fundamental properties of dual problems, Other formulations of dual problems, Complementary slackness, Unbounded solution in the primal, Dual simplex algorithm, Alternative derivation of	15

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	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 M24-MAT-414 NON-COMMUTATIVE RINGS

With effective from the Session: Scheme; 2024-25 , Syllabus; 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 i.e. differential polynomial rings, group rings, skew group rings, triangular rings, Hurwitz's rings of integral quaternion's, DCC and ACC in triangular rings, 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, Wedderburn-Artin Theorem, Schur's Lemma, Minimal ideals, Amitsur Theorem on non-inner derivations. 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, Von Neumann regular rings, E. Snapper's Theorem. 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, Levitzki theorem , Density Theorem, 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 ,

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	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. Hilbert's Twist, Differential polynomial rings, Group rings, Skew group rings, Triangular rings, D.C.C. and A.C.C. in triangular rings. 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. Indecomposable ideals. Inner derivation δ. δ-simple rings. Amitsur Theorem on non-inner derivations.	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. Von Neumann regular rings. E. Snapper's Theorem. Amitsur Theorem on radicals of polynomial rings.	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. Density Theorem. Structure theorem for left primitive rings.	15
IV	Sub-direct products of rings. Subdirectly reducible and irreducible rings. Birchoff's Theorem. Reduced rings. G.Shin's Theorem.	15

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

	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.

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K.U. KURUKSHETRA

PC-4 M24-MAT-415 PRACTICAL-4

With effective from the Session: Scheme; 2024-25 , Syllabus; 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

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

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 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.	30
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.	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.)

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

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.

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OEC M24-OEC-331 Mathematical Tools For Other Disciplines

Session: 2025-2026			
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

Chairman
Deptt. of Mathematics
K.U. KURUKSHETRA

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

<u>Instructions for Paper- Setter:</u> 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	

Chairman
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K.U. KURUKSHETRA

• 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.

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EEC M24-MAT-416 EMPLOYABILITY SKILLS IN MATHEMATICS

With effective from the Session: Scheme; 2024-25 , Syllabus; 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.			

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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. Introduction to. Mathematical. Statistics. Robert V. Hogg. Allen T. Craig,, Low price Indian

edition by Pearson Education

6. Probability and Statistics for Engineers. Richard A. Johnson, Irwin Miller, John Freund
7. Mathematical Statistics with Applications. Irwin Miller, Marylees Miller, Pearson Education
8. The R Software-Fundamentals of Programming and Statistical Analysis -Pierre Lafaye de Micheaux, Rémy Drouilhet, Benoit Liquet, Springer 2013
9. A Beginner's Guide to R (Use R) By Alain F. Zuur, Elena N. Ieno, Erik H.W.G. Meesters, Springer 2009

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