

**Curriculum for MS Program
Department of Mathematics
University of Dhaka**



(Effective for 2024-2025 and onwards)

(Group A: Non-Thesis Group, 32 Credits & Group B: Thesis Group, 36 Credits)

Curriculum for MS Program

Department of Mathematics

University of Dhaka



(Effective for 2024-2025 and onwards)

The Department offers MS (Masters of Science) program in Mathematics. The MS program has duration of 01 academic year for Non-Thesis Group and 1.5 academic years for Thesis Group. In the program, there is provision for taking up thesis work, subject to the approval of the academic committee of the department.

Each student in **Group A (Non-Thesis Group)** of the program has to take **Seven** courses (each of 4 credits), while each student in **Group B (Thesis Group)** has to take **Six** courses, out of the courses enumerated below, subject to conditions laid down by the academic committee.

Group A: Non-Thesis Group

32 Credits

Credit Requirement

7 Courses, 28 Credits

Viva Voce 4 Credits

Group B: Thesis Group

36 Credits

Credit Requirement

6 Courses, 24 Credits

Thesis 8 Credits (Thesis Report 6 Credits & Presentation 2 Credits)

Viva Voce 4 Credits

Curriculum for MS Program
Department of Mathematics
University of Dhaka



List of Departmental Courses for MS Program

(Group A: Non-Thesis Group, 32 Credits & Group B: Thesis Group, 36 Credits)

(Effective for 2024-2025 and onwards)

Course No.	Course Name	Credits
MTMS 501	THEORY OF GROUPS	4 Credits
MTMS 502	THEORY OF RINGS AND MODULES	4 Credits
MTMS 503	ADVANCED NUMBER THEORY	4 Credits
MTMS 504	REAL FUNCTION THEORY	4 Credits
MTMS 505	COMPLEX FUNCTION THEORY	4 Credits
MTMS 506	GENERAL TOPOLOGY	4 Credits
MTMS 507	FUNCTIONAL ANALYSIS	4 Credits
MTMS 508	LIE GROUPS AND LIE ALGEBRAS	4 Credits
MTMS 509	FUZZY MATHEMATICAL STRUCTURES	4 Credits
MTMS 510	DIFFERENTIAL AND INTEGRAL EQUATIONS	4 Credits
MTMS 511	OPERATIONS RESEARCH	4 Credits
MTMS 512	NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS	4 Credits
MTMS 513	GEOMETRY OF DIFFERENTIAL MANIFOLDS	4 Credits
MTMS 514	DYNAMICAL SYSTEMS	4 Credits
MTMS 515	MATHEMATICAL BIOLOGY	4 Credits
MTMS 516	OPERATIONS MANAGEMENT	4 Credits
MTMS 517	QUANTITATIVE FINANCIAL RISK MANAGEMENT	4 Credits
MTMS 518	FLUID MECHANICS AND COMBUSTION THEORY	4 Credits
MTMS 519	SPECIAL TOPICS	4 Credits
MTMS 590	MS THESIS	8 Credits
MTMS 599	VIVA VOCE	4 Credits

MTMS 501: THEORY OF GROUPS			
Course Code: MTHS 501 Course Title: THEORY OF GROUPS	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: Theory of groups and representations is key to many branches of sciences and mathematics such as studying symmetries in geometry, Conservation laws of physics are related to the symmetry of physical laws under various transformations, group theory predicted the existence of many elementary particles before they were found experimentally. The structure and behavior of molecules and crystals depends on their different symmetries. Group theory shows up in many other areas of geometry and Topology. Examples include different kinds of groups, such as the fundamental group of a space. Classical problems in algebra have been resolved with group theory. Cryptography uses a lot of group theory. Different cryptosystems use different groups. This a course that may be studied for its own sake or from view point of applications.			
Course Objectives: By the end of the module, students should be familiar with the topics listed in the Course Contents. In particular, students will be able to prove the Class Equation for finite Groups, learn the techniques to prove Sylow Theorems and their applications for analyzing the structures of Finite Groups of given orders. They should be able to find Extensions and Split Extensions of groups; find Representation using Matrix; prove Schur's Lemma, Maschke's Theorems; find Group Characters.			
Course Contents: 1. Finite Abelian Group and Free Group: Fundamental theorem of finite Abelian group, Free products of groups and Free groups. 2. Group Action: Conjugation, Class equation if finite group, Orbit Stabilizer theorem. 3. Sylow Theory: Finite p-groups, classification of Groups of order p, p^2, pq, p^3. 4. Group Extensions: Direct Products, Cyclic Extensions, Split Extensions, Semi-direct Product, Wreath Products, and Tensor product. 5. Series of Groups: Solvable, Super solvable, Nilpotent Groups and their subgroups; Commutator Group, Composition series, Normal series, Factor Groups; Upper and Lower Central Series. 6. Group Representation: Permutational and Matrix Representation of Groups, Reducibility, Schur's Lemma, Maschke's Theorem. 7. Group Character: Group Characters, Reducible, Irreducible, Faithful Characters; Orthogonality of First and Second Kind.			
Course Learning Outcomes (CLOs): After the successful completion of the course, students will be able to: CLO1: To understand basic ideas and applications of Groups. CLO2: To get introduced to different terminologies and properties of Finite Groups. CLO3: To get familiar with different classes of Groups, such as Symmetry Groups, Permutation Groups, Dihedral Groups, Klein4 Groups.			

CLO4: To find and prove the Class Equation for Finite Groups.
CLO5: To learn the techniques of proofs of Sylow Theorems in the module.
CLO6: To learn to apply Representation Theory of Groups and decomposition into irreducible representations to find Group Characters of Finite Groups.
CLO7: to find Group Characters of Finite Groups.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4		×		×		×		×	×	×		
CLO5	×	×	×	×	×		×	×		×	×	
CLO6	×		×	×		×	×	×		×	×	×
CLO7	×	×	×	×		×	×	×	×	×	×	×

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Finite Abelian Group and Free Group	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Group action	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Sylow Theory	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Group Extensions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Series of Groups	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Group Representation	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Group Character	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. David S. Dummit, Richard M. Foote, Abstract Algebra, John Wiley and Sons Inc.
2. Joseph A. Gallian, Contemporary Abstract Algebra, Cengage Learning.
3. W. Ledermann. Introduction to Group Characters, Cambridge University Press.
4. I. D. Macdonald, The Theory of Groups, Oxford University Press.
5. Thomas W. Judson, Abstract Algebra: Theory and Application, Orthogonal Publishing.

MTMS 502: THEORY OF RINGS AND MODULES			
Course Code: MTHS 502 Course Title: THEORY OF RINGS AND MODULES	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: A ring is an important fundamental concept in algebra and includes integers, polynomials and matrices as some of the basic examples. Ring theory has applications in number theory and geometry. A module over a ring is a generalization of vector space over a field. The study of modules over a ring R provides us with an insight into the structure of R. In this course we shall develop ring and module theory leading to the fundamental theorems of Wedderburn and some of its applications.			
Course Objectives: By the end of the course the student should understand: 1. The importance of rings and modules as central objects in algebra and some of its applications. 2. The basic structure and theory of rings and modules. 3. How to develop this theory to investigate important classes of integral domains? 4. The concept of a module as a generalization of a vector space and an Abelian group. 5. The classification of any finitely generated module as a homomorphic image of a free module. 6. Simple modules, Schur's lemma. Radical, simple and semi simple artinian rings. Examples. 7. Semi-simple modules, artinian modules, their endomorphism. Examples. 8. The Wedderburn-Artin theorem.			
Course Contents: 1. Topics in the Theory of Rings: Polynomial rings over Unique Factorization Domain (UFD), Wedderburn's and Jacobson's Theorems, the Radical, Semisimple and Simple rings. 2. Rings of Fractions: Rings of fractions and embedding theorems, local rings and Noetherian rings, Rings with Ore conditions and related theorems. 3. Field Theory: Irreducible Polynomials and Eisenstein criterion, Algebraic extensions of fields, Splitting fields and Finite fields. 4. Modules and Vector Spaces: Definition and examples, submodules and direct sums, R-homomorphisms and quotient modules, completely reducible and free modules, projective and injective modules, Noetherian and Artinian rings and modules. Wedderburn-Artin theorem.			
Course Learning Outcomes (CLOs): After the successful completion of the course, students will be able to:			

CLO1: See the relations between algebra and its applications in and outside mathematics.

CLO2: To get introduced to different terminologies and properties of Finite Groups

CLO3: Become familiar with rings and fields, and understand the structure theory of modules over a Euclidean domain along with its implications

CLO4: Write precise and accurate mathematical definitions of objects in ring theory.

CLO5: Use mathematical definitions to identify and construct examples and to distinguish examples from non-examples

CLO6: Validate and critically assess a mathematical proof.

CLO7: To understand how every finitely generated module is a homomorphic image of a free module.

CLO8: Use a combination of theoretical knowledge and independent mathematical thinking to investigate questions in ring theory and to construct proofs.

CLO9: Write about ring theory in a coherent, grammatically correct and technically accurate manner.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	
CLO6	×	×	×	×		×	×	×	×	×	×	×
CLO7	×	×	×	×		×	×	×	×	×	×	×
CLO8	×	×	×	×		×	×	×	×	×	×	×
CLO9	×	×	×	×		×	×	×	×	×	×	×

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Topics in the Theory of Rings	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Rings of Fractions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Field Theory	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Modules and vector spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. Hiram Paley and Paul M. Weichsel. A First Course in Abstract Algebra, Holt, Rinehart and Winston
2. S Lang, Algebra, Springer
3. Thomas W Hungerford, Algebra, Springer
4. P.B. Bhattacharya, S.K. Jain & S.R. Nagpaul, Basic Abstract Algebra, Cambridge University Press
5. David S. Dummit, Richard M. Foote, Abstract Algebra, John Wiley & Sons, Inc.

MTMS 503: ADVANCED NUMBER THEORY

Course Code: MTHS 503	Credit Hours: 4.00 Hrs/Week	Year: MS	Semester:
Course Title: ADVANCED NUMBER THEORY	Total Marks: 100		
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards

Rationale:

Number theory is a broad subject with many strong connections with other branches of mathematics. The idea of the course is to give a solid introduction to quadratic fields and algebraic number theory. It will be bridging the gap between elementary number theory and the systematic study of advanced topics.

Course Objectives:

By the end of the course the student should understand:

1. Learn quadratic field specially, Euclidean quadratic fields
2. Get idea on quadratic residues, and law of quadratic reciprocity.
3. Learn the distribution of prime numbers. An extended idea on prime number theory and several arithmetical functions related to prime number theory.
4. Get an idea on Algebraic Number theory.

Course Contents:

1. **Quadratic Fields:** Arithmetic of quadratic fields, Euclidean quadratic fields.
2. **Quadratic Residuacity:** Quadratic residues and nonresidues, Euler criterion, Legendre symbol, Gauss's lemma, law of quadratic reciprocity, Jacobi's symbol.
3. **Average Orders of Arithmetic Functions:** Lim sup, Lim inf, average orders of arithmetical functions.
4. **Distribution of Prime Numbers:** Bertrand's postulate, Chebyshev's theorem, the function $\theta(x)$ and $\psi(x)$. The prime number theory; elementary proof via Selbdr's lemma, complex analytical proof.
5. **Primes in Arithmetic Progressions:** Characters of an abelian group, L-functions, Dirichlet's proof of infinitude of primes in arithmetic progressions.

6. Algebraic Number Theory: Noetherian ring and Dedekind domains, ideal classes and the unit theorem, units in real quadratic field.												
Course Learning Outcomes (CLOs):												
After the successful completion of the course, students will be able to:												
CLO1. Arithmetic of Euclidian quadratic field. quadratic residues, Jacobi’s symbol, gauss lemma, and law of quadratic reciprocity. They can extend their idea on Quadratic residuacity for further ideas.												
CLO2: Arithmetic functions and average orders of arithmetic functions												
CLO3: The distribution of prime numbers. An extended idea on prime number theory and several arithmetical functions related to prime number theory, the function $\theta(x)$ and $\psi(x)$. They will see the elementary proof as well as complex analytical proof of prime number theorem.												
CLO4: Get an idea on Algebraic Number theory and get direction for future study on this area.												
Mapping of CLOs with PLOs:												
CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:												
Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies							Assessment Strategies			
CLO1	Quadratic Fields	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO2	Quadratic Residuacity	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO3	Average orders of Arithmetic Functions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO4	Distribution of Prime Numbers	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO5	Primes in Arithmetic Progressions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO6	Algebraic Number Theory	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
Evaluation: In-course Assessment: 30 Marks . Final Examination (Theory, 4 Hours): 70 Marks . Eight (08) questions of equal value will be set, of which any Five (05) are to be answered.												

References:

1. G.H. Hardy and E M Wright. An introduction to the theory of numbers, Oxford University Press.
2. Kenneth Ireland, Michael Rosen, A Classical Introduction to Modern Number Theory, Springer New York.
3. Ivan Niven, H. S. Zuckerman, H. L. Montgomery, An Introduction to The Theory of Numbers, John Wiley and sons.
4. S. Rose. A course in number theory, Oxford University Press.
5. P. Samuel, Algebraic Theory of Numbers, Dover Publication.

MTMS 504: REAL FUNCTION THEORY

Course Code: MTHS 504	Credit Hours:	Year: MS	Semester:
Course Title:	4.00 Hrs/Week		
REAL FUNCTION THEORY	Total Marks: 100		
Course Teacher:	Course Type:	Pre-requisite:	Academic Session:
	Theory		2024-2025 and onwards

Rationale:

This is a continuation of a course on introduction to measure theory in n -dimensional Euclidian space offered in the senior year of the undergraduate program. The general abstract theory of measure, integration, and their applications is in order for a complete knowledge of the subject.

Course Objectives:

The course's objectives include introducing students to the ideas of abstract measure and its properties, integration of real function on an abstract measure space and its properties, and finally their applications in modern analysis.

Course Contents:

1. **Topics of Lebesgue Integration on R :** Uniform integrability, Convergence in Measure, Characterization of Riemann Lebesgue integrability, Vitali convergence theorem, continuity, absolute continuity, and differentiability of monotone functions.
2. **General Measure Spaces:** Measures and measurable sets, measure induced from the outer measure, an extension of a pre-measure to a measure, signed the measure, Hahn and Jordan decomposition.
3. **Integration over General Measure Spaces:** Measurable functions. Integration of measurable functions, the Radon-Nikodym derivative, and its properties.
4. **Construction of some Particular Measures:** Product measure and theorem of Fubini and Toneli, Caratheodory outer measure, and Hausdorff measures in a metric space.
5. **Measure and Topology:** Construction of Radon measures, Bair measures. Kakatuni's fixed point theorem, Invariant Borel measures, and von Neumann's theorem.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1: Students will learn the abstract theory of measures,

CLO2: Students will learn the abstract theory integrations,

CLO3: Students will learn the abstract theory applications in modern analysis

CLO4: Students will learn the abstract theory of measure space

CLO5: Students will learn the abstract theory of Topology.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Topics of Lebesgue Integration on $\mathbb{R}$	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	General measure spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Integration over general measure spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Construction of some particular measures	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Measure and Topology	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: 30 Marks. Final Examination (Theory, 4 Hours): 70 Marks.

Eight (08) questions of equal value will be set, of which any Five (05) are to be answered.

References:

1. H.L. Royden, P.M. Fitzpatrick. Real Analysis, PHI

2. Gerald B. Folland, Real Analysis Modern Techniques and their applications. John Wiley & Sons Inc.

MTMS 505: COMPLEX FUNCTION THEORY			
Course Code: MTHS 505	Credit Hours:	Year: MS	Semester:
Course Title: COMPLEX FUNCTION THEORY	4.00 Hrs/Week Total Marks: 100		
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards

Rationale:

Complex analysis is indeed one of the classical subjects with most of the main results extending back into the nineteenth century and earlier. Yet, the subject is far from dormant. It is a launching point for many areas of research and it continues to find new areas of applicability, from pure mathematics to applied physics. A graduate course in Complex Analysis has the potential to address many learning outcomes that are important in studying mathematics. The subject has connections to several other mathematical areas and it provides students with opportunities to build a deeper cognitive mathematical framework.

Course Objectives:

This course is intended both for continuing mathematics students that presents an introduction to some advanced topics of contemporary complex analysis. The purpose is to prepare the student to independent work in these topics and specially to use the methods of complex analysis in other areas of mathematics (for example harmonic analysis and differential equations) as well as in applied areas (fluid dynamic, signal analysis, statistics). The students should be able to participate in scientific discussions and conduct researches on high international level in contemporary and classical complex analysis and its applications.

Course Contents:

1. **Convergence:** Uniform convergence of power series. Weierstras's theorem. Absolute and uniform convergence of infinite products.
2. **Analytic Functions:** Open mapping theorem, Maximum modulus principle, Convex functions, Hadamard three-circles theorem. Caratheodory's inequality. Theorems of Poisson, Jensen, Borel and Caratheodory. Space of analytic functions.
3. **Harmonic Functions:** Basic properties, Mean value theorem. Maximum modulus principle, Poisson's Kernel, Harmonic functions of a disc. Dirichlet problem on a disc.
4. **Power Series:** Basic Properties, Relations among power series, Fourier series and Dirichlet series. Sufficient conditions of regular and singular points. Theorems of Hurwitz, Vitali and Montel.
5. **Entire Functions:** Basic properties, Order, type. Growth properties of entire functions with their Zeros. Jensen's Inequality for entire function. Expression of order and type in terms of Taylor coefficients. Hadamard product of entire functions, order and type.
6. **The Space C^n :** Introduction to the theory of analytic function of several complex variables. Formal power series about z in C^n , Poly-cylinder, Distinguished boundary. Reinhardt domain, analytic function. Complex holomorphic functions. Taylor series expansion. Cauchy's integral.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1. Explain the fundamental concepts of complex analysis and their role in modern mathematics and applied contexts

CLO2: Demonstrate accurate and efficient use of complex analysis techniques

CLO3: Demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from complex analysis

CLO4: Apply problem-solving using complex analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Convergence	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Analytic Functions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Harmonic Functions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Power Series	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Entire Functions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	The Space C^n	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. A.I. Markushevich, Theory of functions of a complex variable. Volume I, & Vol. II. Prentice-Hall, INC. N.J
2. Ralph Philip Boas, Entire Functions, Academic Press Inc. New York
3. Salomon Bochner and William Ted Martin, Several Complex variables
4. L.I. Ronkin, Theory of entire functions of several complex variables
5. Bruce P. Palka, An Introduction to Complex Function Theory, UTM Springer.

MTMS 506: GENERAL TOPOLOGY			
Course Code: MTHS 506	Credit Hours: 4.00 Hrs/Week	Year: MS	Semester:
Course Title: GENERAL TOPOLOGY	Total Marks: 100		
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards

Rationale:

Geometry has grown out of efforts to understand the world around us, and has been a central part of mathematics from the ancient times to the present. Topology has been designed to describe, quantify, and compare shapes of complex objects. Together, geometry and topology provide a very powerful set of mathematical tools that is of great importance in mathematics and its applications. This module will introduce the students to the mathematical foundation of modern geometry based on the notion of distance. We will study metric spaces and their transformations. Through examples, we will demonstrate how a choice of distance determines shapes, and will discuss the main types of geometries. An important part of the course will be the study of continuous maps of spaces. A proper context for the general discussion of continuity is the topological space, and the students will be guided through the foundations of topology. Geometry and topology are actively researched by mathematicians and we shall indicate the most exciting areas for further study.

Course Objectives:

The main objective of this topic is to compare several notions that describe convergence in topological spaces.

The objectives of this course are to:

1. discussion of product topologies and introduce quotient spaces
2. introduce convergence of nets and filters in a topological space
3. demonstrate concepts of countability and separation axioms, notion of Lindelöf space, proof of Urysohn's Lemma. To give the idea how a topological space depends upon the distribution of open sets in the space and introduce the connection between different spaces such as regular spaces, completely regular spaces, and normal spaces, Urysohn metrization theorem (Statement) and Tietze Extension theorem (Statement).
4. introduce student the concept of compactness by describing generalization of finiteness and Heine-Borel theorem to demonstrate notions of compactness and compactification constructions. Introduce the notion of different types of connected spaces and the relation between path-wise and local connectedness, components, path components, locally path connectedness.
5. introduce to the concept of uniform topological space and metrizable space, and their relation.
6. introduce to the concept of Functional spaces and establish a relation between point-wise and uniform convergences
7. introduce students to the notion of Commutative Topological Groups, Bases, Subgroups and Quotient groups, completion of topological groups, continuous homomorphisms, Groups of functions
8. develop the student's ability to handle abstract ideas in topology to understand real world applications

Course Contents:

1. **Product and Quotient Topological Spaces:** Constructing continuous functions, Pasting lemma, Maps into products, Product topology, Uniform topology on $\mathbb{R}^J$, Uniform limit theorem, Quotient topology.
2. **Convergence:** Convergence of nets and filters.

3. Countability and Separation Properties: Lindelo f space, Regular spaces, Completely regular spaces, Normal spaces, Characterization of Normality, Urysohn lemma, Statements of Urysohnmetrization theorem and Tietze Extension theorem. 4. Compactness and Connectedness: Compact and locally compact spaces, Uniform continuity theorem, Compactification, Path connectedness, locally connectedness, components, Path components, Locally path connectedness 5. Uniform Spaces: Uniform stability and uniform metrizability. 6. Function Spaces: Topology of pointwise convergence, Topology of uniform convergence, Compact open topology. 7. Topological Groups: Topological group, Elementary properties, Bases, Subgroups and Quotients of topological groups, completion of topological groups, Continuous homomorphisms, Groups of functions, Uniformities and metrization.												
Course Learning Outcomes (CLOs):												
After the successful completion of the course, students will be able to:												
CLO1. learn the idea of different product topologies.												
CLO2: learn the notation of quotient spaces.												
CLO3: understand to work with various notions of compactness and be familiar with various compactification constructions.												
CLO4: learn about connected spaces. They will also understand the relation between Pathwise and local connectedness, and components, path components, locally path connectedness.												
CLO5: gain knowledge of Functional spaces and establish a relation between point-wise and uniform convergences. They will able to distinguish uniform and point-wise convergences												
CLO6: study the important relation: “If a uniformity is metrizable, so is the uniform topology it generates. In the opposite direction, metrizability of the uniform topology does not imply that the uniformity itself is metrizable”.												
CLO7: learn the notion of different properties of commutative topological groups.												
Mapping of CLOs with PLOs:												
CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	
CLO6	×	×	×	×	×	×	×	×	×	×	×	
CLO7	×	×	×	×	×	×	×	×	×	×	×	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:												
Course Learning Outcome (CLO)	Topic				Teaching-Learning Strategies				Assessment Strategies			
CLO1	Product and quotient topological spaces				Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector				Class test and final written examination, assignment, viva			

CLO2	Convergence	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Countability and Separation Properties	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Compactness and Connectedness	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Uniform spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Function spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Topological Groups	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
Evaluation: In-course Assessment: 30 Marks. Final Examination (Theory, 4 Hours): 70 Marks. Eight (08) questions of equal value will be set, of which any Five (05) are to be answered.			
References: 1. Munkres. James, Topology, Pearson. 2. J. Kelly, General Topology. 3. G.F. Simmons, Introduction to Topology and Modern Analysis 4. James Dugundji. Topology, William C Brown Pub, 1966. 5. K. D. Joshi, Introduction to General Topology, Wiley Eastern Limited.			

MTMS 507: FUNCTIONAL ANALYSIS			
Course Code: MTHS 507	Credit Hours:	Year: MS	Semester:
Course Title: FUNCTIONAL ANALYSIS	4.00 Hrs/Week Total Marks: 100		
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: This course will cover the foundations of functional analysis in the context of topological linear spaces and normed linear spaces. This course is a natural follow of the course Topology; while the main focus of convex sets and hyperplanes, semi-norms, locally convex spaces, weak topology, compact convex sets, duality in Banach spaces. Then the linear analysis is on Hilbert spaces with its rich geometrical structures will work with normed linear spaces. The Big Theorems (Uniform Boundedness, Open Mapping and Closed Graph) will be presented and several applications will be analyzed. The important notion of duality will be developed in Banach and Hilbert spaces and an introduction to spectral theory for compact operators will be given. Moreover, Bilinear and quadratic forms, symmetric operators, normal and self-adjoint operators and spectral analysis in Hilbert Spaces for bounded self-adjoint operators and unbounded self-adjoint operators will be analyzed. Despite working in this more general framework many results			

on Nonlinear Compact Operators and Monotonicity will be re-introduced in this course in more general form. For example, Banach Fixed point theorem with applications, Schauder fixed point theorem, Frechet derivative, Newton's method for nonlinear operators, positive and monotone operators will be introduced.

Course Objectives:

1. Facility with the main, big theorems of functional analysis.
2. Learn the fundamental concepts of Topological Linear Spaces and study of the properties of bounded linear maps between topological linear spaces of various kinds.
3. Ability to use duality in various contexts and theoretical results from the course in concrete situations.
4. Capacity to work with families of applications appearing in the course, particularly specific calculations needed in the context of famous theorem.
5. Be able to produce examples and counter examples illustrating the mathematical concepts presented in the course.
6. Understand the statements and proofs of important theorems and be able to explain the key steps in proofs, sometimes with variation.

Course Contents:

1. **Linear Operators in Normed Spaces:** Continuity and boundedness, spectral theory in finite-dimensional normed spaces, spectral properties of bounded linear operators.
2. **Compact Linear Operators on Normed Spaces:** Spectral properties, equations involving compact linear operators, Fredholm type operators and their properties.
3. **Self-Adjoint Linear Operators:** Spectral properties, positive operators and their square root, projection operators, spectral family, spectral representation.
4. **Unbounded Linear Operators in Hilbert Space:** Hilbert-adjoint operators, symmetric and self-adjoint linear operators, spectral properties of self-adjoint linear operators, spectral representation, unitary operators and self-adjoint linear operators, multiplication operator and differentiation operator.
5. **Nonlinear Compact Operators and Monotonicity:** Schauder fixed point theorem, Frechet derivative, Newton's method for nonlinear operators, positive and monotone operators.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1. know and use the properties of topological linear spaces. Also, explain the concepts of Convex sets and hyperplanes, seminorms, locally convex spaces, weak topology, compact convex sets, duality in Banach spaces.

CLO2: get familiar with the Linear Operators, in particular Continuity and boundedness, fundamental properties of bounded operators, uniform boundedness principle, Open Mapping and Closed Graph theorem, conjugate of bounded linear operators, adjoint operator and its duality, bounded linear operators in Hilbert spaces, unbounded linear operator.

CLO3: understand the concept of spectral analysis of linear operators and be able to analyze the necessary problems and theorems on the spectrum and the resolvent operator, spectrum of a bounded linear operator and compact operators.

CLO4: get familiar of spectral analysis in Hilbert Spaces and describe the basic terminologies appeared in bilinear and quadratic forms, symmetric operators, normal and self-adjoint operators, the spectral theorem for bounded self-adjoint operators, unbounded self-adjoint operators.

CLO5: learn on Nonlinear Compact Operators and Monotonicity and deal with the Fixed point theorems and to recognize their applications.

CLO6: compute Frechet derivative and apply Newton's method for nonlinear operators, positive and monotone operators.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	x											
CLO2	x	x	x		x	x	x	x				
CLO3	x	x	x	x	x	x	x	x	x	x		
CLO4	x	x		x	x	x		x	x	x		
CLO5	x	x	x	x	x	x	x	x	x	x	x	
CLO6	x	x	x	x	x	x	x	x	x	x	x	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Linear Operators in Normed Spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Compact Linear Operators on Normed Spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Self-Adjoint Linear Operators	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Unbounded Linear Operators in Hilbert Space	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Nonlinear Compact Operators and Monotonicity	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. A.E. Taylor- Introduction to Functional analysis, John Wiley & Sons, Inc.
2. V. Hutson and J.S. Pym- Applications of Functional Analysis and Operator theory, Academic press
3. W. Rudin- Functional Analysis, McGraw-Hill, Inc. International
4. Y. Eidelman, V. Milman and A. Tzolomitis, Functional Analysis an Introduction, American Mathematical Society
5. E. Kreyszig, Introduction to Functional Analysis with Applications, Wiley

MTMS 508: LIE GROUPS AND LIE ALGEBRAS			
Course Code: MTHS 508 Course Title: LIE GROUPS AND LIE ALGEBRAS	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: Lie groups are continuous groups of symmetries, like the group of rotations of n-dimensional space or the group of invertible n-by-n matrices. In studying such groups, we can use tools from calculus to linearize our problems, which leads us to the notion of a Lie algebra: a vector space with an antisymmetric product associated to any Lie group, which remembers everything about its algebraic structure. For example, the Lie algebra associated with the group of rotations of 3-space is just 3-dimensional Euclidean space with (twice) the vector cross product. Lie algebras appear in mathematics in many ways. - They represent the local structure of Lie groups, groups with a differentiable structure. - They represent infinitesimal actions on vector spaces, actions satisfying rules like the Leibniz rule $d(fg) = fdg + gdf$. They represent the non-commutativity of an associative algebra. We will be studying Lie algebras from several points of view: algebraic; combinatorial; and geometric.			
Course Objectives: This course is divided into two halves. In the first half we introduce the notion of a closed linear group and the relationship between a closed linear group and its linear Lie algebra which will serve you well in later part of the course. We prove that any closed linear group becomes a Lie group. In the second half of the course, we turn our attention to the connection between Lie algebras and Lie groups. This will involve some ideas from geometry (manifolds and tangent spaces). At the title suggests, this is a first course in the theory of Lie groups and Lie algebras. We focus on the so-called matrix Lie groups since this allows us to cover the most common examples of Lie groups in the most direct manner and with the minimum amount of background knowledge. We mention the more general concept of a general Lie algebra of a Lie group, but do not spend much time working in this generality. After some motivating examples involving quaternions, rotations and reflections, we give the definition of a matrix Lie group and discuss the well-studied examples, including the classical Lie groups. We then study the topology of Lie groups, their maximal tori, and their centres. We conclude with a discussion of differential (adjoint) representation.			
Course Contents:			

- 1. Manifolds:** Some basic notation and terminology, Manifolds and differentiable manifold; some important results on manifolds.
- 2. Closed Linear Groups:** Topological groups, Lie Algebras of the closed linear groups.
- 3. Lie Groups and Lie Algebras:** Lie groups, a matrix representation of the topological group R . Linear Lie groups, Lie subgroups; The exponential map of a Lie group, General Lie algebras; Convergent power series, matrix power series.
- 4. Analyticity of Lie Groups:** The Lie algebra defined by a Lie group, Local coordinates, Abelian and reductive Lie groups.
- 5. Correspondence between Lie Groups and Lie Algebras:** Tangent space and vector fields, Invariant vector fields, Invariant differential operators, One-parameter subgroups, Differential representation.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1. mathematical intuition and problem-solving capabilities.

CLO2: understanding of which tool is appropriate to tackle which problem

CLO3: ability to find information through tools like the world-wide web to solve problems;

CLO4: ability to use computers to illustrate arguments;

CLO5: competency in mathematical presentation, and written and verbal skills.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	x											
CLO2	x	x	x		x	x	x	x				
CLO3	x	x	x	x	x	x	x	x	x	x		
CLO4	x	x		x	x	x		x	x	x		
CLO5	x	x	x	x	x	x	x	x	x	x	x	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Manifolds	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Closed Linear Groups	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Lie Groups and Lie Algebras	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Analyticity of Lie Groups	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Correspondence between Lie Groups and Lie Algebras	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. Anthony W. Knap. Lie Groups Beyond an Introduction, Birkhäuser.
2. F.W. Warner. Foundations of Differentiable Manifolds and Lie groups, Springer.
3. M. Spivak. Calculus on Manifolds, Westview Press.
4. A. A. Sagle and R. E. Walde, Introduction to Lie Groups and Lie Algebras, Academic Press.
5. Joachim Hilgert Karl-Hermann Neeb, Structure and Geometry of Lie Groups, Springer Monographs in Mathematics.

MTMS 509: FUZZY MATHEMATICAL STRUCTURES

Course Code: MTHS 509 Course Title: FUZZY MATHEMATICAL STRUCTURES	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards

Rationale:

A fuzzy set can be defined mathematically by assigning to each possible individual in the universe of discourse a value representing its grade of membership in the fuzzy set. The aim is to introduce the main components of fuzzy set theory and to overview some of its applications. In constructing a model, we always attempt to maximize its usefulness. The aim to construct a model is closely connected with the relationship among three key characteristics such as, complexity, credibility, and uncertainty. Lotfi A. Zadeh [1965b] has introduced a theory whose object ‘fuzzy set’ are sets with boundaries that are not precise. The membership in a fuzzy set is not a matter of affirmation or denial, but rather a matter of a degree. Fuzzy set theory has become an essential part of the curriculum in different discipline of science, especially in applied mathematics, engineering, and technology. The concept of fuzzy sets, fuzzy topology, and fuzzy algebra have been used in decision making in fuzzy environment, fuzzy cluster analysis, fuzzy control system. The concepts of fuzzy sub-groupoids, fuzzy subgroups, fuzzy monoid, fuzzy normal subgroups, fuzzy automata theory and pattern recognition, and coding theory have been dealt with.

Course Objectives:

The main objective of this topic is to teach several notions that describe different properties and methods fuzzy topological spaces and fuzzy algebra. The objectives of this course are to

1. give basic notion of different terms and operations on fuzzy sets in fuzzy set theory
2. introduce fuzzy relational equations and their solution methods
3. introduce the concepts of fuzzy logic

4. introduce the notion of fuzzy topological spaces, continuous functions, fuzzy metric spaces, fuzzy neighbourhood spaces, fuzzy convergence fuzzy compact spaces, fuzzy connectedness
5. introduce fuzzy substructures, fuzzy monoid fuzzy automata, fuzzy subgroup and pattern recognition, coding theory theory.

Course Contents:

1. **Review of basics of Fuzzy sets:** Constructing Fuzzy sets, Operations on Fuzzy sets, t-norm and s-norm, α -Cuts and strong α -Cuts, Extension principle, Measurement of fuzziness, Fuzzy relations, Fuzzy similarity, Fuzzy ordering, Pattern classification based on fuzzy relations.
2. **Fuzzy relational equations:** General discussion, Problem partitioning, Solution methods, Fuzzy relation equations based on sup-i compositions, Fuzzy relation equations based on inf- ω_1 compositions.
3. **Fuzzy logic:** Multivalued logics, Fuzzy propositions, Fuzzy quantifiers, linguistics hedges, Approximate reasoning.
4. **Fuzzy topological spaces:** Fuzzy topologies, F-Continuous functions, Fuzzy metric spaces, Fuzzy neighborhood spaces, Fuzzy convergence, Fuzzy compact spaces, Fuzzy connectedness, Fuzzy components.
5. **Fuzzy algebra:** Fuzzy substructures of algebraic structures, Fuzzy monoids, and fuzzy automata theory, Fuzzy subgroups and pattern recognition, Free fuzzy monoids, and coding theory.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1. explain basic notion of different terms and operations on fuzz sets in fuzzy set theory.

CLO2: understand fuzzy relational equations and can apply their solution methods.

CLO3: earn knowledge about fuzzy logic and explain the concepts of fuzzy logic.

CLO4: explain the notion of fuzzy topological spaces, continuous functions, fuzzy metric spaces, fuzzy neighbourhood spaces, fuzzy convergence fuzzy compact spaces, fuzzy connectedness.

CLO5: gain knowledge about fuzzy substructures, fuzzy monoid fuzzy automata, fuzzy subgroup and pattern recognition, coding theory.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
-------------------------------	-------	------------------------------	-----------------------

CLO1	Review of basics of Fuzzy sets	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Fuzzy relational equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Fuzzy logic	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Fuzzy topological spaces	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Fuzzy algebra	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. J. N. Mordeson & P.S. Nair. Fuzzy mathematics: An introduction for Engineers and Scientists, Physica-Verlag Heidelberg
2. G.J. Klair, U.S. Clair & B. Yuan. Fuzzy Set Theory: Foundations and applications, Prentice Hall
3. R. Lowen. Fuzzy Set Theory, Springer
4. Liu Ying-Ming & Luo Mao-Kang. Fuzzy Topology, River Edge, NJ: World Scientific Pub.
5. H.J. Zimmermann. Fuzzy set Theory and its Applications, Springer

MTMS 510: DIFFERENTIAL AND INTEGRAL EQUATIONS			
Course Code: MTHS 510	Credit Hours:	Year: MS	Semester:
Course Title: DIFFERENTIAL AND INTEGRAL EQUATIONS	4.00 Hrs/Week Total Marks: 100		
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: This course is intended to develop rigorous practical and analytic skills in differential and integral equations (DIE). It is intended to illustrate various applications of differential and integral equation to technical problems as well. The laws of nature are expressed as differential and integral equations. Scientists and engineers must know how to model the world in terms of differential and integral equations, and how to solve those equations and interpret and analyze the solutions. This course focuses on theoretical aspects of linear and nonlinear differential and integral equations and their applications in science and engineering. More details are given in the course goals below.			
Course Objectives:			

The main objective of the course is for students to:

1. give knowledge on rigorous mathematical analysis of solutions of first order differential equations
2. have a solid knowledge on stability and time long dynamics of solutions of differential equations (DEs).
3. learn to classify integral equations (IEs), and have deeper understanding on existence and uniqueness of solutions of Integral equations of Volterra and Fredholm type.
4. be competent to interpret the solutions of DIE.
5. have a solid knowledge on applications of DIE and analyze real-life problems.
6. be familiar with integro-differential equations with real life examples.
7. be able to apply numerical methods of integral equations.
8. detail Symmetric kernels and eigenvalue analysis.
9. be exposed with research and further opportunities.

Course Contents:

1. **Existence and Uniqueness Theorem of Differential Equations:** Review of existence and uniqueness theorem with some examples, fixed point methods, and existence theorem for vector valued IVP (higher dimensional cases).
2. **Periodic Solutions:** Periodic solutions of linear and non-linear differential and integral equations, Asymptotic behavior of solutions of linear differential equations.
3. **Stability Analysis:** Stability analysis of linear and nonlinear differential equations, Lyapunov stability analysis.
4. **Integral Equations:** Conversions of IVP's to integral equations, existence, uniqueness and general properties of solutions of Volterra integral equations, linear and non-linear systems of VIE's resolving kernels, Fredholm theory of IE's, semi-analytic solutions of a class of integral equations of Volterra and Fredholm types, singular Integral equations, Integro-Differential equations.
5. **Numerical Solutions of Integral Equations:** Degenerate kernel methods, Projection Methods, Quadrature Methods, Rainer Kress Methods.
6. **Hilbert- Schmidt Theory:** Symmetric kernels, Complex Hilbert space, orthogonal system of functions, fundamental properties of eigenvalues and eigenfunction for symmetric kernels, Hilbert-Schmidt theorem with applications.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1: explain the concept of existence and uniqueness of solutions of differential equations

CLO2: analyze stability and time long dynamics of solutions of DEs.

CLO3: classify integral equations and analyze existence-uniqueness theorems of integral equations.

CLO4: obtain analytic and semi-analytic solutions of a class of integral equations.

CLO5: analyze symmetric kernels and relevant theorems.

CLO6: apply quadrature approximations for solutions of integral equations.

CLO7: analyze and implement projection methods for IEs and IDEs.

CLO8: apply Integral equations and Integro-differential equations in various branches science and engineering.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	x		x									
CLO2	x		x	x			x		x			x
CLO3	x		x									
CLO4	x		x		x		x					
CLO5	x		x	x					x			
CLO6	x		x	x			x	x				
CLO7	x		x	x	x		x	x	x			
CLO8	x		x	x	x		x	x	x	x		x

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1 CLO2	Existence and Uniqueness Theorem of Differential Equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO1 CLO2	Existence and Uniqueness Theorem of Differential Equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO1 CLO2	Stability Analysis and Lyapunov stability analysis Periodic Solutions	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3 CLO4	Integral Equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	semi analytic solutions of Integral Equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Hilbert- Schmidt theory	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Numerical Solutions of Integral Equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Numerical Solutions of Integral Equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO8	Applications	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. Ravi P. Agrawal and Donal O' Regan, An Introduction to Ordinary Differential Equations, Springer.
2. Fred Brauer and John A. Nohel, Ordinary differential equations.
3. Masujima, M., Weinheim, Applied Mathematical Methods of Theoretical Physics: Integral Equations and Calculus of Variations, Germany, Wiley.

4. D. E. Atkinson, Numerical solutions of integral equations.
5. M. Rahman, Integral Equations and their Applications, WIT press.

MTMS 511: OPERATIONS RESEARCH			
Course Code: MTHS 511	Credit Hours:	Year: MS	Semester:
Course Title:	4.00 Hrs/Week		
OPERATIONS RESEARCH	Total Marks: 100		
Course Teacher:	Course Type:	Pre-requisite:	Academic Session:
	Theory		2024-2025 and onwards
Rationale: Operations Research (OR), also called Management Science, is the study of scientific approaches to decision-making problems. Through mathematical modeling, it seeks to design, improve and operate complex systems in the best possible way. This is a comprehensive course covering several areas of OR. The module covers topics that include: linear programming, bounded variable simplex algorithm, transportation and assignment problem, job sequencing, network model, dynamic programming, integer programming, game theory and nonlinear programming. Analytic techniques and computer packages will be used to solve problems facing different real life application oriented decision making problems.			
Course Objectives: 1. Formulate a real-world problem as a mathematical programming model. 2. Implement and solve the model using various software packages. 3. Solve specialized linear programming problems like the transportation and assignment problems. 4. Solve network models like the shortest path, minimum spanning tree, and maximum flow problems. 5. Understand the applications of, basic methods for, and challenges in integer programming. 6. Understand how to model and solve problems using dynamic programming. 7. Learn optimality conditions for single- and multiple-variable unconstrained and constrained nonlinear optimization problems, and corresponding solution methodologies			
Course Contents: 1. Basics of Operations Research: Introduction, Definition, Characteristic, Necessity, Scope, Classification of problems, Types of mathematical models, Review of Linear Programming, Bounded Variable Simplex Algorithm. 2. Transportation and Assignment Problem: Introduction, Formulation, Relationship with LP, Solution procedure, Travelling Salesman Problem, Applications. 3. Network Models: Network definitions, Shortest Route problem, Minimal Spanning Tree problem, Maximal-Flow problem. 4. Integer Programming: Introduction, Pure integer and Mixed integer programming problem, Solution of IP using Branch and Bound Algorithm, Cutting-plane Algorithm, Applications.			

5. **Sequencing Problem:** Sequencing problem processing n jobs through two machines, n jobs through three machines, two jobs through m machines, n jobs through m machines and approaches to more complex sequencing problems.
6. **Game Theory:** Introduction, Zero-sum game and Non-zero-sum game, Minimax-maximin pure strategies, Mixed strategies and Expected payoff, solution of (2×2) , $(2 \times n)$ and $(m \times 2)$ games, solution of $(m \times n)$ games by linear programming and Brown's algorithm. Evolutionary games: Basic concepts of evolutionary games; Scope of evolutionary games; Estimation of Nash equilibrium of several 2×2 games (Prisoner's dilemma, Chicken/snowdrift, stag-hunt, harmony/trivial, etc. using replicator dynamics.
7. **Dynamic Programming:** Introduction, Resource allocation problem, investment Problem, Production scheduling problem, Stagecoach problem, Equipment replacement problem.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1: Students will be able to model and solve some real life oriented problems such as, transportation and assignment problem. Also they will be able to connect these problems with the network models.

CLO2: They will be familiarized with job scheduling problems along with their solution procedures.

CLO3: Application of bounded variable Linear program will be understood in modeling several network models.

CLO4: They will learn modeling with integer program along with the solution techniques

CLO5: Students will get some basic backgrounds on Dynamic programming and Game theory.

CLO6: They will be able to solve constrained and unconstrained nonlinear optimization problems

CLO7: Students will be able to develop applications using the familiar software tools (EXCEL/SOLVER, LINDO, MATLAB, MATHEMATICA, etc.) to solve problems.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	
CLO6	×	×	×		×	×	×	×				
CLO7	×	×	×	×	×	×	×	×	×	×		

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Basics of Operations Research	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

CLO2	Transportation and Assignment Problem	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Network Models	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Integer Programming	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Sequencing Problem	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Game Theory	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Dynamic Programming	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**. **Eight (08)** questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. Operations Research, Applications and Algorithms- Wayne L. Winston, Thomson Learning.
2. Operations Research, An Introduction- Hamdy A. Taha, Pearson Prentice Hall.
3. Operations Research- A. Ravindran, D.T. Philips, J.J. Solberg, John Wiley and Sons.
4. Introduction to Operations Research, F. Hiller, G. Lieberman, Mc Graw-Hill.
5. Evolutionary dynamics: Exploring the equations of life, Martin Nowak, Harvard University Press.

MTMS 512: NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS			
Course Code: MTHS 512 Course Title: NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards

Rationale:

There are a lot of naturally occurred processes which can be described using ordinary and partial differential equations (ODEs and PDEs). A thorough knowledge of these processes are acquired solving the relevant equations. This course deals with numerical methods of various types of ordinary and partial differential equations. In particular, finite difference methods (FDMs) for linear and nonlinear ordinary differential equations as well as for elliptic, parabolic, hyperbolic partial differential equations will be discussed. Moreover, students will learn finite element methods (FEMs) in details.

Course Objectives:

1. To learn FDM for linear and nonlinear ODEs.
2. To know how to solve PDEs using FDMs.
3. To find numerical integration using FEM.
4. To provide a detailed knowledge about FEM to solve PDEs.
5. To learn how to solve eigenvalue problem using FEM.

Course Contents:**Finite Element Method**

1. **Introduction to FEM:** Discretization, Construction of basis functions, Numerical integration; coordinate transformation, local and global derivatives, mesh generation, h-p convergence.
2. **Galerkin Method:** BVP for Ordinary Differential Equations, 2D Poisson's and Laplace's equations, one space dimensional heat and Wave equations.
3. **Weighted Residuals Method:** Subdomain, Matrix formulation, Modified Galerkin method to solve 1-D linear and nonlinear BVP.
4. **Finite Element Solution of BVP:** Outline of FE procedures for Poisson's and Laplace's equations, Matrix formulation, Element concept, Triangular, Rectangular and Quadrilateral elements (linear and quadratic elements).
5. **Variational Formulation of ODEs (BVP):** Variational Functional and Construction of functionals, Rayleigh-Ritz method and finite elements.

Finite Difference Method

6. **Elliptic PDEs:** Review the solution of 2-space variables Poisson's and Laplace's equations, matrix formulation of the model, Stability, and error analysis of methods.
7. **Parabolic PDEs:** Review of 1D problems, Heat equation in 2-space variables, Matrix formulation, Forward, Backward and Crank-Nicolson methods, ADI method, Von Neumann Stability and error analysis of methods.
8. **Hyperbolic PDEs:** Wave equation in 1-space variables, Different types of explicit and implicit methods, Convergence and stability analysis, Wave equation in 2-space variables, Lax-Wendroff and Courant-Friedrichs-Lewy explicit methods, Wendroff implicit method, Wave equation in time-dependent and two space dimensions, Convergence and stability analysis.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

- CLO1:** Ability to solve linear and nonlinear ODEs employing FDM
CLO2: Analyze PDEs using relevant FDMs.
CLO3: Find numerical integration using FEM.
CLO4: Apply FEM in solving PDEs.
CLO5: Solve eigenvalue problem utilizing FEM.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Introduction to FEM	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Galerkin Method	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Weighted Residuals Method	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Finite Element Solution of BVP	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Variational Formulation of ODEs (BVP)	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Elliptic PDEs	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Parabolic PDEs	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO8	Hyperbolic PDEs	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. P. E. Lewis and J. P. Ward, The finite element method: Principles and Application, Addison Wesley.
2. M. A. Celia and W. G. Gray, Numerical Methods for Differential Equations, Prentice-Hall Int. Inc.
3. G. D. Smith, Numerical solution of Partial differential equations, Clarendon press, Oxford
4. A. R. Mitchell and R. Wait, Finite Element Method in Partial Differential Equations, John Wiley & Sons Ltd.

5. S. C. Brenner and L. R. Scott, The Mathematical Theory of Finite Element Methods, third edition, springer, 2000.

MTMS 513: GEOMETRY OF DIFFERENTIAL MANIFOLDS			
Course Code: MTHS 513 Course Title: GEOMETRY OF DIFFERENTIAL MANIFOLDS	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: Geometry of Differential Manifolds is based on three dimensional basic vector geometry of curves and surfaces with calculus. Understanding of this course students will precede to learn other areas of mathematics such as Differentiable Manifolds, Riemannian Manifolds, Theory of Relativity and cosmology etc. Upon the successful completion of this course students will able to apply the concepts of surfaces to find which surface are minimal surfaces and also to know Weingarten, Gauss and Codazzi equations, Theorema Egregium, fundamental theorem of surface theory etc. Students will know the concepts of developable surfaces, ruled surfaces, Gaussian curvature, Geodesics, Geodesic curvature, Liouville's formula, Clairaut's theorem, Bonnet's formula and Gauss-Bonnet theorem. Students will learn about Conformal, isometric and geodesic mapping, Tissot's theorem. Theory of differential functions, charts, atlases, differentiable manifolds, smooth map on Manifolds, Tangent space, Tangent bundles, C^∞- vector fields and Lie brackets of vector fields on Manifolds, φ - related vectorfields.			
Course Objectives: The objectives of this course are: 1. To give knowledge on mathematical concepts of space curve and surfaces, this course is very much useful. 2. Students will know the concepts of geodesic curvature and its formulae, Liouville's formula, geodesic on a surface of revolution, Clairaut's theorem, Bonnet's formula, geodesics on Liouville surface, Gauss-Bonnet theorem. 3. Students will learn about Manifolds structure on a topological space, C^∞- vector fields on manifolds etc.			
Course Contents: 1. Surfaces and Properties of Surface: Minimal surfaces, theorem of minimal surfaces, general solution of the natural equations, Riccati equation and its solution, equation of Weingarten, Gauss and Codazzi and their applications, Theorema Egregium, fundamental theorem of surface theory. 2. Developable and Ruled Surfaces: Envelop, characteristic, edge of regression, developable surface, property of lines of curvature on developable, ruled surface,			

fundamental coefficients and Gaussian curvature for ruled surface, tangent plane to a ruled surface.

3. **Geodesics on a Surface:** Geodesics, differential equation of geodesics, geodesics on plane, surface, sphere, right circular cone, right helicoid, cylinder, torus etc., geodesic curvature and its formulae, Liouville's formula, geodesic on a surface of revolution. Clairaut's theorem, Bonnet's formula, geodesics on Liouville surface, Gauss-Bonnet theorem, torsion of a geodesic, geodesic parallel.
4. **Mapping of Surfaces:** Mapping, homeomorphism, isometric lines and correspondence, Minding theorem, conformal, isometric and geodesic mapping, Tissot's theorem.
5. **Differentiable Manifold:** Theory of differentiable functions, coordinate functions, charts and atlases, complete, compatibility, differentiable structures, differentiable manifolds, local representation of a function for charts, induced topology on a manifolds.
6. **Topology of a Manifold:** Manifold structure on a topological space, properties of induced topology, topological restrictions on manifolds.
7. **Differentiation on a Manifold:** Partial differentiations, equivalence relation and class, smooth map on manifolds, derivation of smooth function and tangent vector, structure of tangent space, independent of tangency relation, tangent space, tangent bundles, tensor and exterior bundles, tangent map on manifolds.
8. **Vector Fields on a Manifold:** C^∞ -vector fields on manifolds, coordinates of vector fields, set of vector fields, theorem on vector fields and its coordinates, Lie brackets of vector fields and properties of $\mathcal{L}_X$ -related vector fields.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1. Apply Gauss and Weingarten equations to find out Theorema Egregium and Codazzi's equations.

CLO2. Have to know about minimal surface, Riccati equation and its solution with some problem.

CLO3. Know how to check developable surface and how to find Gaussian Curvature and which surface is ruled surface or skew.

CLO4. How to find the geodesics for surfaces of plane, sphere, right circular cone, right helicoid, cylinder and torus and so on and to know geodesic curvature and its theorem.

CLO5. Illustrate different types of mapping and their properties and proof Tissot's theorem by using non-conformal mapping.

CLO6. Know about manifolds, charts, atlases and compatibility by using composite of two charts, local representation.

CLO7. Illustrate the differential structure of manifold with C^∞ -function and topology.

CLO8. Gather Knowledge about smooth map, tangent space, tangent bundles, structure of tangent space map on manifolds.

CLO9. Earn knowledge about the conception of $\mathcal{L}_X$ -related vector fields, to know lemma and its applications into proposition of Lie brackets of vector fields.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	x		x	x	x				x	x	x	x
CLO2	x		x	x	x			x	x		x	x
CLO3	x		x	x	x	x	x	x	x		x	x
CLO4	x	x	x	x	x	x	x	x	x	x	x	x

CLO5	x	x	x	x	x	x	x	x	x	x	x	x
CLO6	x		x	x	x				x	x	x	x
CLO7	x		x	x		x		x	x	x	x	x
CLO8	x		x	x	x	x	x	x	x	x	x	x
CLO9	x		x	x				x	x			x

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Theorema Egregium, Weingarten, Gauss and Codazzi and their applications, fundamental theorem of surface theory.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	general solution of the natural equations, Riccati equation and its solution.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Minimal surfaces, developable, and ruled surface.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Geodesics, geodesics on different surfaces, geodesic curvatur.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Mapping, conformal, isometric and geodesic mapping, Tissot's theorem.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	C^∞ - function smooth function. manifolds, charts, atlases and compatiability by using composite of two charts, local representation.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Partial differentiations, equivalence relation and class, smooth map on manifolds, derivation of smooth function and tangent vector.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO8	Smooth map, smooth map, tangent space, tangent bundles, structure of tangent space map on manifolds.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO9	C^∞ -vector field, Lie brackets of vector fields, ϕ - related vector fields.	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. C. E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press, London.
2. F. W. Warner, Foundations of Differentiable Manifolds and Lie groups, Scott, Foresman and Company, Glenview, Illinois, London
3. S. C. Mital and D. C. Agarwal, Differential Geometry, Krishna Prakashan Mandir, India.
4. D. J. Struik, Lectures on Classical Differential Geometry, Addison-Wesley Publishing Company, Inc. USA.
5. F. Brickell and R. S. Clark, Differentiable Manifolds: An Introduction, Van Nostrand Reinhold Company, London.

MTMS 514: DYNAMICAL SYSTEMS			
Course Code: MTHS 514 Course Title: DYNAMICAL SYSTEMS	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: Dynamics deals with change which evolve in time. Whether the system in question settles down to equilibrium, keep repeating in cycles, or does something more complicated, it is the dynamics that we use to analyze the behavior in various places of science.			
Course Objectives: At the end of the year students should be able to know: 1. The qualitative properties of dynamics and to understand asymptotic behavior 2. To classify equilibria by their stability, invariant manifolds and topological types 3. Identify fundamental differences between linear and nonlinear dynamical systems 4. Construct and interpret phase portraits of maps and flows 5. Identify fixed points and periodic points and determine their stability 6. How qualitative structure of the flow can change as parameters are varied 7. Unpredictable long-term behavior in a deterministic dynamical system 8. Characterization and measurements of chaos such as sensitive dependence on initial conditions and Lyapunov exponents 9. Use fractals to predict or analyze various biological processes or phenomena.			
Course Contents: 1. Discrete Dynamical Systems: One parameter family of maps, contraction and expanding map, fixed and periodic points, family of logistic maps, tent map, linear map, iterative maps, quadratic maps, Smale horseshoe map, and their stability analysis. 2. Chaotic Dynamical systems: Definitions of chaos, sensitive dependence on initial conditions, orbit structure, Cantor set, basin of attractor and repeller, strange attractors, Li-Yorke chaos and Lyapunov exponents. 3. Differential Dynamical Systems: One and two dimensional linear and nonlinear differential equations, sink, source and saddle points, hyperbolic fixed point, and their stability; population models; Henon map, Lorenz map; manifold and sub-manifold, stable and unstable manifold, center manifold theorem, Hartman-Grobman theorem, Hadamard-Perron theorem, Smale theorem. 4. Bifurcations: Bifurcations, bifurcation points, Saddle-node bifurcation, period-doubling bifurcation, pitchfork bifurcation, transcritical bifurcation, Hopf bifurcation, backward bifurcation. 5. Symbolic Dynamical Systems: Sequence spaces, shift map, symbolic dynamics, sub-shift of finite type.			

6. Fractal and Multi-fractal: Basic concept of fractals, self-similarity, fractal dimension, chaos game, fractals in nature, Koch curve, Sierpinski triangle, Sierpinski carpet, Multi-fractal.												
Course Learning Outcomes (CLOs):												
After the successful completion of the course, students will be able to:												
CLO1. extend their knowledge of calculus to solve problems in difference (and maybe differential) equations.												
CLO2: students improve problem solving skills.												
CLO3: understand the concepts of dynamical systems and to learn how to function in a work group.												
CLO4: graphical analysis of dynamical systems and understand phase portraits.												
CLO5: recognize when a dynamical system exhibits chaotic behavior												
CLO6: generate fractals and find the topological dimension and fractal dimensions.												
Mapping of CLOs with PLOs:												
CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	x											
CLO2	x	x	x		x	x	x	x				
CLO3	x	x	x	x	x	x	x	x	x	x		
CLO4	x	x		x	x	x		x	x	x		
CLO5	x	x	x	x	x	x	x	x	x	x	x	
CLO6	x	x	x	x		x	x	x	x	x	x	x
CLO9	x	x	x	x	x	x	x	x	x	x	x	x
Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:												
Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies							Assessment Strategies			
CLO1	Discrete Dynamical Systems	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO2	Chaotic Dynamical systems	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO3	Differential Dynamical Systems	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO4	Bifurcations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO5	Symbolic Dynamical Systems	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
CLO6	Fractal and Multi-fractal	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector							Class test and final written examination, assignment, viva			
Evaluation: In-course Assessment: 30 Marks . Final Examination (Theory, 4 Hours): 70 Marks .												
Eight (08) questions of equal value will be set, of which any Five (05) are to be answered.												
References:												

1. S H Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, And Engineering, Westview press, 2000.
2. R.L. Devaney. A First course in chaotic dynamical systems, Westview Press, 1992.
3. R.A. Holmgren. A first course in discrete dynamical systems, Springer, 2001.
4. S. Banerjee, M K Hassan, S. Mukherjee & A Gowrisankar, Fractal Patterns in Nonlinear Dynamics and Application, CRC press.
5. A. Katok and B. Hasselblatt. Introduction to modern theory of dynamical systems, CUP, Cambridge, 1995.

MTMS 515: MATHEMATICAL BIOLOGY			
Course Code: MTHS 515 Course Title: MATHEMATICAL BIOLOGY	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: To provide students with the mathematical tools used to study and solve a variety of problems in biology at different scales. Mathematical Biology is one of the most rapidly growing and exciting areas of Applied Mathematics. This is because recently developed experimental techniques in the biological sciences, are generating an unprecedented amount of quantitative data.			
Course Objectives: By the end of the module the student should be able to: 1. to analyze simple models of biological phenomena using mathematics 2. to reproduce models and fundamental results of biological systems 3. introduce the student to advanced mathematical modeling in the Life Sciences 4. apply methods in the module to new problems inside the scope of Mathematical Biology 5. explore methods for solving the models and discuss the implications of the predictions.			
Course Contents: 1. Single Species Continuous Models: Introduction to linear and nonlinear population models, Sharpe-Lotka age-dependent population model, Gurtin-MacCamy age-dependent population model. 2. Multi Species Continuous Models: Two species linear and nonlinear population models, multi-species models, stability. Migration Modeling. 3. Microbial Population Models: Microbial population, dynamics of microbial competition, chemostat model and stability of equilibrium points. 4. Dynamics of Infectious Diseases: Virus dynamics, Dynamics of infectious diseases, AIDS/HIV models, dynamics of hepatitis B virus, age-dependent epidemic model, drug therapy, vaccination effects, Immunization and other public health intervention strategies, Modeling vector-borne diseases.			

5. Dynamics with Diffusion: Reaction-Diffusion models, single and multi-species diffusion models, competition model with diffusion, epidemic model with diffusion, Pattern formations in systems of reaction-diffusion equations. 6. Stochastic Model: Concepts in probability, stochastic Processes, Brownian motion, martingales, stochastic linear and nonlinear models of population. Continuous and discrete time Markov Chain.												
Course Learning Outcomes (CLOs):												
After the successful completion of the course, students will be able to:												
CLO1: the applications of ODE models in a variety of biological systems												
CLO2: making the student aware how to choose and use different modeling techniques in different areas												
CLO3: reaction-diffusion equations and their applications in biology												
CLO4: introduce the connections between biological questions and mathematical concepts												
CLO5: develop the mathematics of dynamical systems, linear algebra, differential equations and difference equations through modeling biological systems												
CLO6: explore the utility of using mathematical tools to understand the properties and behavior of biological systems.												
Mapping of CLOs with PLOs:												
CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	
CLO6	×	×	×	×		×	×	×	×	×	×	×
Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:												
Course Learning Outcome (CLO)	Topic				Teaching-Learning Strategies				Assessment Strategies			
CLO1	Discrete Dynamical Systems				Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector				Class test and final written examination, assignment, viva			
CLO2	Multi Species Continuous Models				Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector				Class test and final written examination, assignment, viva			
CLO3	Microbial Population Models				Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector				Class test and final written examination, assignment, viva			
CLO4	Dynamics of Infectious Diseases				Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector				Class test and final written examination, assignment, viva			
CLO5	Dynamics with Diffusion				Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector				Class test and final written examination, assignment, viva			

CLO6	Stochastic Model	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
Evaluation: In-course Assessment: 30 Marks. Final Examination (Theory, 4 Hours): 70 Marks. Eight (08) questions of equal value will be set, of which any Five (05) are to be answered.			
References: 1. F Brauer & C Castillo-Chavez, Mathematical models in population biology and epidemiology, Springer-Verlag, New York, 2001. 2. Maia Martcheva, An Introduction to Mathematical Epidemiology, Texts in Applied Mathematics, Springer, 2015. 3. J.D. Murray, Mathematical Biology, Springer, 1993. 4. H. L. Smith & P. Waltman, Theory of Chemostat, CUP, 1995. 5. M. A. Nowak & R. M. May, Virus Dynamics, Mathematical Principles of Immunology and Virology, 2000.			

MTMS 516: OPERATIONS MANAGEMENT			
Course Code: MTHS 516	Credit Hours:	Year: MS	Semester:
Course Title:	4.00 Hrs/Week		
OPERATIONS MANAGEMENT	Total Marks: 100		
Course Teacher:	Course Type:	Pre-requisite:	Academic Session:
	Theory		2024-2025 and onwards
Rationale: Operations activities, such as forecasting, choosing a location for an office or plant, allocating resources, designing products and services, scheduling activities, and assuring and improving quality are core activities and often strategic issues in business organizations. Production Management or Operations Management is the management of systems or processes that create goods and/or services. The material in this course is intended as an introduction to the field of operations management. The field of operations management is dynamic, and very much a part of the good things that are happening in business organizations. Much of what the students learn will have practical application.			
Course Objectives: 1. To give knowledge on the ways to manage the business organization efficiently. 2. Students will be able to learn the formulating procedure of different types of management tools. 3. It will help the students to apply the knowledge gather from this course in real life problems.			
Course Contents:			

1. **Chapter 1: Strategic Capacity Planning:** Introduction to Operations Management (OM), the scope of OM, Productivity, Strategy, Competitiveness. Strategic capacity decision, Defining and measuring capacity, Evaluating capacity alternatives.
2. **Chapter 2: Quality Control:** Management of quality, Statistical process control, Variations and control, Control charts, Process capability, Improving process capability, Capability analysis.
3. **Chapter 3: Forecasting:** Elements of good forecast, Accuracy and control of forecasting, Applications of Forecasting, Judgmental Forecasting Methods, Time Series, Forecasting Methods for a Constant-Level Model, Incorporating Seasonal Effects into Forecasting Methods, An Exponential Smoothing Method for a Linear Trend Model, Holt's method, Winter's method, Box-Jenkins Method, Causal Forecasting with Linear Regression.
4. **Chapter 4: Inventory Control:** Components of Inventory Models, basic inventory models (Economic order quantity (EOQ) model, EPQ model, fixed order interval model, Single period model, Deterministic Continuous-Review Models, Deterministic Periodic-Review Model, Stochastic Continuous-Review Model, Stochastic Single-Period Model for Perishable Products, Stochastic Periodic-Review Models, Larger Inventory Systems in Practice.
5. **Chapter 5: Planning and Scheduling:** Scheduling in high-volume systems, intermediate-volume systems, low-volume systems, Scheduling methods of Linear Programming, Scheduling jobs through two work centers, Minimizing scheduling difficulties, scheduling the work force.
6. **Chapter 6: Supply Chain Management:** Value chains, supply chains, demand chains, need for supply chain management, benefits of supply chain management, managing supply chain, evaluating shipping alternatives, Global supply chain, e-commerce, effective supply chain, optimizing the supply chain.
7. **Chapter 7: Waiting line and Simulation:** Goal of Waiting line, Measuring system performance, Queuing models, The Essence of Simulation, Advantage and limitations of using simulations, applications of Simulation, Generation of Random Numbers, Generation of Random Observations from a Probability Distribution, Variance-Reducing Techniques, Regenerative Method of Statistical Analysis, Monte-Carlo simulation.
8. **Chapter 8: Project Management:** Behavioral aspect of project management, Key decisions in project management, PERT (program evaluation and review technique), CPM (critical path method), Deterministic time estimates, Probabilistic time estimates, Applications.

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

- CLO1:** be an expert in product and service design
- CLO2:** process selection, technology selection.
- CLO3:** design of work systems, location planning, facility planning.
- CLO4:** quality improvement of goods and services;
- CLO5:** forecasting,
- CLO6:** capacity planning;
- CLO7:** scheduling.
- CLO8:** managing inventory
- CLO9:** manage large scale projects.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	
CLO6	×	×	×	×		×	×	×	×	×	×	×
CLO7	×	×	×	×	×		×	×	×	×	×	×
CLO8	×	×	×	×	×	×	×	×	×	×	×	×
CLO9	×	×	×	×	×	×	×	×	×	×	×	×

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Strategic Capacity Planning	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Quality Control	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Forecasting	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Inventory Control	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Planning and Scheduling	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Supply Chain Management	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Waiting line and Simulation	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO8	Project Management	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO9	Applications	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: In-course Assessment: **30 Marks**. Final Examination (Theory, 4 Hours): **70 Marks**.

Eight (08) questions of equal value will be set, of which any **Five (05)** are to be answered.

References:

1. Operations Management by William J. Stevenson, 7th Edition, McGraw-Hill Higher education.
2. Operations Research by Wayne L. Winston,

3. Introduction to OR by Hillier and Lieberman, 10th Edition, McGraw-Hill Higher education
4. Fundamentals of Management Science by Turban & Merideth.

MTMS 517: QUANTITATIVE FINANCIAL RISK MANAGEMENT			
Course Code: MTHS 517 Course Title: QUANTITATIVE FINANCIAL RISK MANAGEMENT	Credit Hours: 4.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards
Rationale: It is a follow up course with prerequisites of ‘Stochastic Calculus’ and ‘Introduction to Mathematical Finance’. The idea and concept of risk management in Banks, Insurance and other financial institutions are covered from stochastic modelling perspectives. Stock markets volatility modeling and stock derivative price modelling are good part of the course. Back-testing risk measures for stock return and other risk measures for derivative investments are covered. In addition to celebrated Black and Scholes model several non-normal derivative pricing models are covered.			
Course Objectives: **The course instructor will provide the details.			
Course Contents: 1. Risk Management, Financial Returns and the Dynamics: Risk Management and the Firm, A Brief Taxonomy of Risks, Stylized Facts of Asset Returns, Diffusion processes, Jump processes and some GARCH processes for risk management 2. Volatility Modeling: Simple Variance Forecasting, The GARCH Variance Model, Extensions to the GARCH Model, Maximum Likelihood Estimation, Variance Model Evaluation, Using Intraday Information, Empirical Exercises, Chapter References for further reading. 3. Correlation Modeling in Finance: Value at Risk (VaR) for Simple Portfolios, Portfolio Variance, Modeling Conditional Covariances, Modeling Conditional Correlations, Quasi-Maximum Likelihood Estimation, Realized and RangeBased Covariance, VaR from Logarithmic versus Arithmetic Returns, Empirical Exercises, Chapter References for further reading. 4. Modeling the Conditional Distribution in Finance: Visualizing Non-Normality, The Standardized t(d) Distribution, The Cornish-Fisher Approximation to VaR, Extreme Value Theory (EVT), The Expected Shortfall (ES) Risk Measure, Empirical Exercises, Chapter References for further reading. 5. Simulation-Based Methods: Historical Simulation (HS), Weighted Historical Simulation (WHS), Multi-Period Risk Calculations, Monte Carlo Simulation (MCS), Filtered Historical Simulation (FHS), Empirical Exercises, estimating VaR and ES for ARCH/GARCH processes; jump-diffusion processes; fattedailed levy processes; mean			

reverting processes. Review of Vasicek Model, exponential Vasicek model, CIR model, mean reversion +CIR combined model in order to apply risk measures. Chapter References for further reading. 6. Option Pricing: Basic Definitions, Option Pricing under the Normal Distribution, Allowing for Skewness and Kurtosis, GARCH Option Pricing Models, Implied Volatility Function (IVF) Models, The CFG Option Pricing Formula, Empirical Exercises, Chapter References for further reading. 7. Modeling Option Risk: The Option Delta, Portfolio Risk Using Delta, The Option Gamma, Portfolio Risk Using Gamma, Portfolio Risk Using Full Valuation, A Simple Example, Pitfall in the Delta and Gamma Approaches, Empirical Exercises, Chapter References for further reading. 8. Backtesting Risk Models: Backtesting VaRs, Increasing the Information Set, Conditional coverage test, Unconditional coverage test, Independence test, application of backtesting to simulation based models of section 5; Empirical Exercises, Chapter References for further reading.
--

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be able to:

CLO1: Preparing to engage in research degrees in Mathematical Finance and advanced Actuarial Science

CLO2: Having in-depth idea of how stock market models using Brownian motion and Brownian motion with jumps work in stochastic calculus sense

CLO3: Concepts of Implied volatility in derivative markets and Implied volatility models for derivative pricing will help students engage in quantitative research groups of Banks and Insurance companies that deal with derivatives

CLO4: GARCH models for financial econometric with non-stationary distributions in stock return modeling; and risk management through Value-at-Risk (VaR) and Expected Shortfall (ES)

CLO5: Backtesting risk measures to understand the performance of risk measures on practical data.

Mapping of CLOs with PLOs:

CLO/ PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO10	PLO11	PLO12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Risk Management, Financial Returns and the Dynamics	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

CLO2	Volatility Modeling	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Correlation Modeling in finance	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Modeling the Conditional Distribution in finance	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Simulation-Based Methods	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Option Pricing	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Modeling Option Risk	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO8	Backtesting Risk Models	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
Evaluation: In-course Assessment: 30 Marks. Final Examination (Theory, 4 Hours): 70 Marks. Eight (08) questions of equal value will be set, of which any Five (05) are to be answered.			
References: 1. Elements of Financial Risk Management, Peter Christoffersen, Academic Press, 2. A stochastic process toolkit for Risk Management, Damiano Brigo et al. 3. Quantitative Risk Management: Concepts, techniques and tools, Alexander McNeil, Princeton University Press 4. Measuring Market Risk, Kevin Dowd, Wiley.			

Course Code: MTMS 518	Credit Hours: 4.00	Year: MS	Semester:
Course Title: Fluid Mechanics and Combustion Theory	Hrs/Week		
	Total Marks: 100		
Course Teacher:	Course Type:	Pre-requisite:	Academic Session:
	Theory		2024-2025 and onwards

Rationale:

The course deals with theoretical and practical aspects of fluid mechanics and combustion theory. The various topics covered are: conservation of mass, momentum and energy, Navier-Stokes' equation, ideal and potential flows, multicomponent, reacting, ideal-gas mixtures, theories of reaction rates such as Arrhenius law, activation energy, and collision theory of reaction rates. Some of the vital topics covered are solutions of fundamental steady and unsteady problems with constant and variable properties. Basic problems of inviscid and viscous compressible fluids are solved and analyzed. Moreover, this course includes theory and solutions of laminar flames.

Course Objectives:

1. To understand the concept of fluid flow.
2. To understand the flows of steady incompressible fluids.
3. To understand the flows of inviscid and viscous problems.
4. To understand the concept of combustion.
5. To understand about the asymptotic solutions of fundamental combustion problems.

Course Content:

1. **Steady incompressible flow:** Review of preliminaries and governing equations of fluid dynamics, Flow between two coaxial cylinders, Flow between concentric circular cylinders, Flow of two immiscible viscous fluids between two parallel plates, Steady flow of viscous incompressible fluid between two porous parallel plates, Plane Couette flow with transpiration cooling
2. **Unsteady incompressible flow with constant and variable fluid properties:** Unsteady flow of viscous incompressible fluid between two parallel plates, Pulsatile flow between parallel surfaces, Flow in pipe, starting from rest, Basic equations of steady incompressible flow with variable viscosity, Plane Couette and Poiseuille flows of viscous incompressible fluid with variable viscosity.
3. **Temperature distribution in steady incompressible with constant fluid properties:** Derivation of the energy equation, temperature distribution for plane and generalized Couette flows, plane Poiseuille and Hagen-Poiseuille flows, and for a fluid flow between two concentric rotating cylinders.
4. **Flow of inviscid compressible fluids:** Thermodynamic relations for a perfect gas, Basic equations for one-dimensional flow of a gas, Speed of sound in a gas, Mach number and its importance, Isentropic gas flow, Flow through a nozzle, Isentropic gas flow, Elementary analysis of two-dimensional normal and oblique shock waves.
5. **Flow of viscous compressible fluids:** Basic equations in Cartesian and cylindrical coordinates, One-dimensional flow of a compressible viscous fluid, Plane Couette flow, Flow through a circular pipe and between two concentric rotating cylinders.
6. **Theory of laminar flames:** Conservation equations for multicomponent, reacting, ideal-gas mixtures; theories of reaction rates: Arrhenius law, Activation energy, Collision theory of reaction rates, Deflagration wave, Mathematical formulation, Preliminary assumptions and equations, Derivation of energy and diffusion equations, Solution of the diffusion equation when $Le=1$, Derivation of burning rate using large activation energy asymptotics, Theory of Zeldovich, Frank-Kamenetskii, and Semenov.
7. **Velocity and temperature of laminar flames:** Reaction Waves Propagation Through a Combustible Mixture, Velocity and thickness of laminar flames, Temperature and concentration distributions in flames, Normal velocity of flame propagation: Zel'dovich – Frank-Kamenetskii Theory.

8. **Asymptotic solutions of some problems:** Asymptotic analysis of the reaction zone, ignition of a confined mixture by a flat plate, ignition of an unconfined mixture by a flat plate, premixed flame extinction through volumetric heat loss, Frank-Kamenetskii solution.

Course Learning Outcomes:

After the successful completion of the course, students will be able to:

CLO1. Know equations of Navier-Stokes equations and analyze some steady-state problems

CLO2. Gather knowledge about some unsteady problem with constant and variable properties

CLO3. Analyze energy equation and some problems

CLO4. Acquire knowledge about basic problems of inviscid compressible fluids

CLO5. Learn the solutions of some basic problems of viscous compressible fluids

CLO6. Know the basic equations of combustion

CLO7. Study velocity and temperature of some standard laminar flames

CLO8. Asymptotic solutions of some basic problems

Mapping of CLOs with PLOs

CL O/ PL O	PLO 1 (Fun d.)	PL O2 (La b)	PL O3 (Crit . Thin k)	PL O4 (Re s. Skil l)	PL O5 (So c. Skil l)	PL O6 (En g. & Soc.)	PL O7 (Job Skil l)	PL O8 (Ethi cs and Life- long Lear n.)	PL O9 (Ind . & Tea m wor k)	PLO 10 (Proj. Com m.)	PL O 11 (Pr oj. Ma n.)	PL O 12 (Life - long Lear n.)
CL O1	x	x	x	x		x	x					x
CL O2	x	x	x	x		x	x					x
CL O3	x	x	x	x		x	x					x
CL O4	x	x	x	x		x	x					
CL O5	x	x	x	x		x	x					
CL O6	x	x	x	x		x	x					
CL O7	x	x	x	x		x	x					
CL O8	x	x	x	x		x	x					

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

Course Learning Outcome (CLO)	Topic	Teaching-Learning Strategies	Assessment Strategies
CLO1	Steady incompressible flow	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO2	Unsteady incompressible flow with constant and variable fluid properties	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO3	Temperature distribution in steady incompressible with constant fluid properties	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO4	Flow of inviscid compressible fluids	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO5	Flow of viscous compressible fluids	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO6	Theory of laminar flames	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO7	Velocity and temperature of laminar flames	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO8	Asymptotic solutions of some problems	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva
CLO9	Prandtl's boundary layer equations; similarity concepts and similarity solutions of the boundary layer equations	Lecture, recommended textbook, worksheets, printed solutions, use multimedia projector	Class test and final written examination, assignment, viva

Evaluation: Incourse Assessment 30 Marks. Final exam (Theory, 4 hours): 70 Marks. **Eight** questions of equal value will be set, of which **five** are to be answered.

References:

1. M. D. Raisinghania, Fluid Dynamics With Complete Hydrodynamics And Boundary Layer Theory, Revised Edition, 2013.

2. Irvin Glassman and Richard A. Yetter, Combustion, Fourth Edition, 2008.
3. Forman A. Williams, Combustion Theory, Second Edition, 1984.
4. Chung K. Law, Combustion Physics, First Edition, 2006.
5. M. Liberman, Introduction to Physics and Chemistry of Combustion, First Edition, 2008.
6. J. D. Buckmaster and G.S.S. Ludford, Theory of Laminar Flames, 2008.

MTMS 590: MS THESIS			
Course Code: MTHS 590 Course Title: MS THESIS	Credit Hours: 8.00 Hrs/Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2024-2025 and onwards

A student has to earn a minimum Honours CGPA as a requirement of getting entry in **Group B: Thesis Group**. In each academic year, the Departmental Academic Committee determines the minimum CGPA. The students choose his/her supervisor among the faculties of the department subject to approval of the Academic Committee.

Each thesis student is required to work on a specific topic in different fields of mathematics and its applications, prepare a thesis report as a partial fulfillment of requirements for the degree. The thesis work may include original research, review work, and applications of mathematics and may involve fieldwork and use of technology.

Evaluation: The distribution of marks for each thesis shall be as follows:

Thesis Report	: 150 marks (6 Credits)
Thesis Presentation	: 50 marks (2 Credits)

Each thesis report shall be examined by two examiners, both examiners are appointed from outside of the department on the recommendation of the TICC [Thesis Implementation and Coordination Committee]. In case the marks of the two examiners of a thesis report differ by more than 20% a third examiner for that report shall be appointed from amongst the teachers or outside of the department on the recommendation of the TICC. In such cases the final marks shall be determined according to the usual procedure.

Each student is required to present her/his work on the thesis before the TICC who will evaluate the presentation.

The Academic Committee may prepare additional guidelines for evaluation of the projects.

All marks on the projects shall be submitted to the Examination Committee for tabulation with copies to the Controller of Examinations. The thesis reports shall be returned to the TICC for preservation.

The Academic Committee will fix a date for the submission of the project reports to the TICC. Each student must submit three typed copies of her/his thesis report to the TICC on or before the date fixed for such submission.

The TICC, on receiving the reports will arrange the presentation of reports by individual students before the TICC, this presentation should take place soon after the completion of the written examination.

Any student who fails to submit the report on the due date or to present the thesis on the fixed date will not get any credit for this course.

MTH 599: Viva Voce

Credits: 4

Viva Voce on courses taught in the MS Program.