একাডেমিক কাউন্সিলের (২৬-০৯-২০২৩) কার্যবিবরণীর অংশ

কারিকুলাম অনুমোদন

১২৬। সিদ্ধান্ত ঃ বিজ্ঞান অনুষদের (১৯-০৯-২০২৩) সুপারিশ অনুযায়ী গণিত বিভাগের একাডেমিক কমিটির (০৫-০৯-২০২৩ এবং ১২-০৯-২০২৩) সুপারিশ অনুসারে উক্ত বিভাগের ২০২২-২০২৩ শিক্ষাবর্ষে এম এস-এর কোর্স কারিকুলাম {(Group A (Non-Thesis Group 32 Credit)}; {(Group B (Thesis Group 36 Credit)} অনুমোদন

স্মারক নং রেজিঃ/প্রশা-৫/ ৬৮-৭৮-৮০ তারিখ ঃ-১৮/১০-২০২৩

অবগতি ও প্রয়োজনীয় ব্যবস্থা গ্রহণের জন্য নিম্নোক্তগণের নিকট অনুলিপি প্রেরিত হলো ঃ-

(১) ডিন, বিজ্ঞান অনুষদ, ঢাঃ বিঃ।
(২) চেয়ারম্যান, গণিত বিভাগ, ঢাঃ বিঃ।
(৩) ডেপুটি রেজিস্ট্রার (শিক্ষা-৩), ঢাঃ বিঃ।

18 OCT 2023

ডেপুটি রেজিস্ট্রার (প্রশাসন-৫)
ঢাকা বিশ্ববিদ্যালয়।

ড. মোঃ শহীদুল ইসলাম
অধ্যাপক ও চেয়ারম্যান
গণিত বিভাগ, এ এফ মুজিবুর রহমান গণিত ভবন
ঢাকা বিশ্ববিদ্যালয়, ঢাকা ১০০০, বাংলাদেশ
ফোন ঃ (অফিস) ঃ (আইপি) ৯৬৬৬৯১১৪৬৩/৭০৭০
মোবাইল ঃ +৮৮০১৮১৯৪৯৩৭৬৭
ফ্যাক্স (ঢা. বি.) ঃ ৮৮০-২-৫৫১৬৭৮১০
ই-মেইল ঃ mshahid@du.ac.bd, mshahidul11@yahoo.com

ঢাকা বিশ্ববিদ্যালয়

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স্মারক নং- গ/১৪৯৭/২০২৩

তারিখ ঃ ৩০ ভাদ্র ১৪৩০ বঙ্গাব্দ
১৪ সেপ্টেম্বর ২০২৩ খ্রিস্টাব্দ

রেজিস্ট্রার
ঢাকা বিশ্ববিদ্যালয়
ঢাকা ১০০০

মাধ্যম ঃ ডিন, বিজ্ঞান অনুষদ, ঢাকা বিশ্ববিদ্যালয়

বিষয় ঃ গণিত বিভাগের ২০২২-২০২৩ ও ২০২৩-২০২৪ শিক্ষাবর্ষে এম এস এর কারিকুলাম **OBE** ফরমেটে অনুমোদন প্রসঙ্গে

প্রিয় মহোদয়

আপনার অবগতি ও প্রয়োজনীয় ব্যবস্থা গ্রহণের জন্য জানাচ্ছি যে, গত ০৫-০৯-২০২৩ ও ১২.০৯.২০২৩ তারিখের একাডেমিক কমিটির সভায় ২০২২-২০২৩ ও ২০২৩-২০২৪ শিক্ষাবর্ষে এম এস এর কারিকুলাম OBE ফরমেট অনুযায়ী বিশ্ববিদ্যালয় একাডেমিক কাউন্সিলে অনুমোদনের সুপারিশ করা হয়।

এতদ্সঙ্গে কারিকুলাম OBE ফরমেট এর এক কপি প্রেরিত হলো।

বিনীত

১৪/০৯/২৩

ড. মোঃ শহীদুল ইসলাম
অধ্যাপক ও চেয়ারম্যান
গণিত বিভাগ, ঢাকা বিশ্ববিদ্যালয়

Faculty meeting

17 SEP 2023

Non Thesis - 32 credit
Thesis — 36 credit

OBE Based Curriculum
For One-Year MS Program
Department of Mathematics
University of Dhaka

(Effective for 2022-2023 and 2023-2024)

OBE Based Curriculum for One-Year M. S. Program
Department of Mathematics
University of Dhaka
(Effective for 2022-2023 and 2023-2024)

The Department offers M. S. (Masters of Science) program in Mathematics. The M.S. program has duration of one academic year. 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 (6+2) Credits
Viva Voce 4 Credits

List of Courses for M. S. Program

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	SPECIAL TOPICS	4 Credits
MTMS 590	MS THESIS	8 Credits
MTMS 599	VIVA VOCE	4 Credits

Course Code: MTMS-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: 2023-2026

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 fundamentalgroup 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 Content:

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 Extentions, Split Extentions, 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, Maschk'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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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

Course Code: MTMS-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: 2023-2026

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 Content:

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 an 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** (Funda)	**PLO2** (Lab)	**PLO3** (Crit Think)	**PLO4**	**PLO5**	**PLO6**	**PLO7**	**PLO8**	**PLO9**	**PLO 10**	**PLO 11**	**PLO 12**
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	**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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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. Bhattarcharya, 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.

Course Code: MTMS-503 Course Title: ADVANCED NUMBER THEORY	Credit Hours: 4.00 Hrs /Week Total Marks: 100	Year: MS	Semester:
Course Teacher:	Course Type: Theory	Pre-requisite:	Academic Session: 2023-2026

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 fired 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:

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

Course Content:

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 Selbdrg'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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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

Course Code: MTMS-504 **Course Title: REAL FUNCTION THEORY**	**Credit Hours: 4.00 Hrs /Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content:

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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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 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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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.

Course Code: MTMS-505 **Course Title: COMPLEX FUNCTION THEORY**	**Credit Hours: 4.00 Hrs/Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

Rationale:

Complex analysis is indeed is 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 Content:

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 $\mathbf{C}^n$:** Introduction to the theory of analytic function of several complex variables. Formal power series about z in $\mathbf{C}^n$, 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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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.

Course Code: MTMS-506 **Course Title: GENERAL TOPOLOGY**	**Credit Hours: 4.00 Hrs /Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Lindel öf space, proof of Urysohm'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, Urysohnmetrization theorem (Statement) and Tietze Extention 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 pathwise 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 Content:

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 Separationproperties:** Lindelöf space, Regular spaces, Completely regular spaces, Normal spaces, Characterization of Normality, Urysohn lemma, Statements of Urysohnmetrization theorem and TietzeExtention 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:** Uniformisability and uniform metrisability.
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 topoloical groups, completiòn of topological groups, Continuous homomorphisms, Groups of functions, Uniformities and metrisation.

Course Learning Outcomes (CLO's):

After the successful completion of the course, students will be an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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 Separationproperties**	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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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.

Course Code: MTMS-507 **Course Title: FUNCTIONAL ANALYSIS**	**Credit Hours: 4.00 Hrs /Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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, seminorms, 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:

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. 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 Content:

8. **Linear Operators in Normed Spaces:** Continuity and boundedness, spectral theory in finite-dimensional normed spaces, spectral properties of bounded linear operators.
9. **Compact Linear Operators on Normed Spaces**: Spectral properties, equations involving compact linear operators, Fredholm type operators and their properties.
10. **Self-Adjoint Linear Operators:** Spectral properties, positive operators and their square root, projection operators, spectral family, spectral representation.
11. **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.

12. **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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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	**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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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. Tsolomitis, Functional Analysis An Introduction, American Mathematical Society
5. E. Kreyszig, Introduction to Functional Analysis with Applications, Wiley

Course Code: MTMS-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: 2023-2026**

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.

i. They represent the local structure of Lie groups, groups with a differentiable structure.
ii. They represent infinitesimal actions on vector spaces, actions satisfying rules like the Leibniz rule $d(fg) = f\,dg + g\,df$.
iii. 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 Content:

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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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	**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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** are to be answered.

References:

1. Anthony W. Knapp. **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

Course Code: MTMS-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: 2023-2026**

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 charactistics, 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 subgroupoids, 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 topolocal spaces and fuzzy algebra. The objectives of this course are to

1. give basic notion of different terms and operations on fuzz 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 neibourhood 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 Content:

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 an 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 neibourhood 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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

Course Code: MTMS-510 **Course Title: Differential and Integral Equations**	**Credit Hours: 4.00 Hrs/Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite: MTH-303**	**Academic Session: 2023-2024**

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 Content:

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), boundedness of solutions
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 (IDE).
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:

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 Intrgro-differential equations in various branches science and engineering.

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

Mapping of CLOs with PLOs

CLO/ PLO	PLO 1	PLO 2	PLO 3	PL O4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12
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

Evaluation: Incourse Assessment 30 Marks. Final examination (Theory, 4 hours): 70 Marks. **Eight** questions of equal value will be set, of which any **five** 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, WITpress.

Course Code: MTMS-511 **Course Title: OPERATIONS RESEARCH**	**Credit Hours: 4.00 Hrs /Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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:

The objectives of this course are to:

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 Content:

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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** are to be answered.

References:

1. **Operations Research, Applications and Algorithms**- *Wayne L. Winstion,* 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.

Course Code: MTMS-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: 2023-2026**

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 Content:

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

Course Learning Outcomes (CLOs):

After the successful completion of the course, students will be an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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

Course Code: MTMH 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: 2023-2026**

Course Rational:

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 Egreegium, fundamental theorem of surface theory etc. Students will know the concepts of developable surfaces, ruled surfaces, Gaussian curvature, Geodesics, Geodesic curvature, Liouvilles 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:

- To give knowledge on mathematical concepts of space curve and surfaces, this course is very much useful.
- Students will know the concepts of geodesic curvature κ_g 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.
- Students will learn about Manifolds structure on a topological space, C^{∞} - vector fields on manifolds etc.

Course Content:

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, Theoema Egreegium, 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 κ_g 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 Manifolds:** Theory of differentiable functions, coordinate functions, charts and atlases, complete, compatiablity, differentiable structures, differentiable manifolds, local representation of a function between two manifolds for their charts, induced topology on a manifolds.
6. **Topology of a Manifolds:** Manifold structure on a topological space, properties of induced topology, topological restrictions on manifolds.
7. **Differentiation on a Manifolds:** 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 Manifolds:** 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 φ - 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 Egreegium 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 compatiability 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 φ - related vector fields, to know lemma and its applications into proposition of Lie brackets of vector fields.

Mapping of CLOs with PLOs

CLO/ PLO	PLO 1 (Funda)	PLO2 (Lab)	PLO 3 (Crit Think)	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10	PLO 11	PLO 12

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	Theoema Egreegium, 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: Incourse Assessment: **30** Marks. Final examination (Theory, 4 hours): **Full marks: 70. Eight** questions of equal value will be set, of which any **Five** 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, Illiniois, 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: AnIntroduction, Van Nostrand Reinhold Company, London.

Course Code: MTMS-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: 2023-2026**

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 Content:

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, trancritical 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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
CLO1	×											
CLO2	×	×	×		×	×	×	×				
CLO3	×	×	×	×	×	×	×	×	×	×		
CLO4	×	×		×	×	×		×	×	×		
CLO5	×	×	×	×	×	×	×	×	×	×	×	
CLO6	×	×	×	×		×	×	×	×	×	×	×
CLO9	×	×	×	×	×	×	×	×	×	×	×	×

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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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.

Course Code: MTMS-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: 2023-2026**

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 Content:

1. **Single Species Continuous Models:** Introduction to linear and nonlinear population models, Sharpe-Lotka age-dependent population model, Gurtin-MaCamy 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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** are to be answered.

References:

6. F Brauer & C Castillo-Chavez, Mathematical models in population biology and epidemiology, Springer-Verlag, New York, 2001.
7. Maia Martcheva, An Introduction to Mathematical Epidemiology, Texts in Applied Mathematics, Springer, 2015.
8. J.D. Murray, Mathematical Biology, Springer, 1993.
9. H. L. Smith & P. Waltman, Theory of Chemostat, CUP, 1995.
10. M. A. Nowak & R. M. May, Virus Dynamics, Mathematical Principles of Immunology and Virology, 2000.

Course Code: MTMS-516 **Course Title: OPERATIONS MANAGEMENT**	**Credit Hours: 4.00 Hrs/Week** **Total Marks: 100**	**Year: MS**	**Semester:**
Course Teacher:	**Course Type: Theory**	**Pre-requisite:**	**Academic Session: 2023-2026**

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 Content:

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.

Chapter 2: Quality Control

Management of quality, Statistical process control, Variations and control, Control charts, Process capability, Improving process capability, Capability analysis.

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.

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.

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.

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.

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.

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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** are to be answered.

References:

1. Operations Management by William J. Stevenson, 7th Edition, McGrew-Hill Higher education.
2. Operations Research by Wayne L. Winston,
3. Introduction to OR by Hillier and Lieberman, 10th Edition, McGrew-Hill Higher education
4. Fundamentals of Management Science by Turban & Merideth

Course Code: MTMS-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: 2023-2026

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:

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 Content:

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; fattailed 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 an 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 (Funda)	PLO2 (Lab)	PLO3 (Crit Think)	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO 10	PLO 11	PLO 12
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, usę 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: Incourse Assessment **30** Marks. Final examination (Theory, 3 hours) **70** Marks. **Eight** questions will be set of which any **five** 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

MTMS 590: MS THESIS	**Credits: 8**

A student has to earn a minimum Hohours 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)

MTMS 599: VIVA VOCE	**Credits: 4**
Viva Voce on courses taught in the M. S. program.	