# Learning Outcomes Based Curriculum Framework (LOCF)

## for

## Mathematics

अप्रमत्तेन वेद्धव्यम्

**Postgraduate Programme**

**2022**

**Department of Mathematics**

**Cotton University**

**Panbazar, Guwahati**
**Assam**

## PART I

### 1.1 Introduction

Higher education plays a critical role in securing gainful work and/or offering further access to higher education. As a result, improving the quality of higher education should be given top priority in order to enable the next generation of students to acquire the skills, training, and knowledge they need to improve their thinking, comprehension, and application abilities and prepare them to compete, succeed, and excel globally.

The Cotton University envisions all of its programmes in the best interests of its students, and in this effort, it has given all of its Postgraduate courses a new perspective. For all of its Postgraduate programmes, it uses a Learning Outcome-based Curriculum Framework (LOCF).

At the Postgraduate level, the LOCF approach is intended to provide a focused, outcome-based curriculum with an agenda to shape teaching-learning experiences in a more student centric manner. The LOCF strategy has been implemented to enhance students' experiences as they participate in their chosen programme. Students will be prepared for both academics and employment through the Postgraduate Programs.

The syllabus developed for M.Sc. course in Mathematics has the provision of ensuring the integrated personality of the students in terms of providing opportunity for exposure to the students towards Core Courses, Open Elective Courses, Special Courses and Skill Enhancement Courses with special focus on technical, communication and subject specific skills through practical and other innovative transactional modes to develop their employability skills.

### 1.2 Learning Outcomes-based Approach to Curriculum Planning and Development

The basic objective of the learning outcome based approach to curriculum planning and development is to focus on demonstrated achievement of outcomes (expressed in terms of knowledge, understanding, skills, attitudes and values) and academic standards expected of graduates of a programme of study. Learning outcomes specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study.

The expected learning outcomes are used to set the benchmark to formulate the course outcomes, programme specific outcomes, programme outcomes and graduate attributes. These outcomes are essential for curriculum planning and development, and in the design, delivery and review of academic programmes. They provide general direction and guidance to the teaching-learning process and assessment of student learning levels under a specific programme.

The overall objectives of the learning outcomes-based curriculum framework are to:

- help formulate graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes that are expected to be demonstrated by the holder of a qualification;
- enable prospective students, parents, employers and others to understand the nature and level of learning outcomes (knowledge, skills, attitudes and values) or attributes a graduate of a

programme should be capable of demonstrating on successful completion of the programme of study;

- maintain national standards and international comparability of learning outcomes and academic standards to ensure global competitiveness, and to facilitate student/graduate mobility; and
- provide higher education institutions an important point of reference for designing teaching-learning strategies, assessing student learning levels, and periodic review of programmes and academic standards.

### 1.3 Key outcomes underpinning curriculum planning and development

The learning outcomes-based curriculum framework is a framework based on the expected learning outcomes and academic standards that are expected to be attained by graduates of a programme of study. The key outcomes that underpin curriculum planning and development include Graduate Attributes, Programme Outcomes, Programme Specific Outcomes, and Course Outcomes.

#### 1.3.1 Graduate Attributes

The disciplinary expertise or technical knowledge that has formed the core of the university courses. They are qualities that also prepare graduates as agents for social good in future. Some of the characteristic attributes that a graduate should demonstrate are as follows:

1. **Disciplinary knowledge**: Capable of demonstrating comprehensive knowledge and understanding of one or more disciplines
2. **Research-related skills**: A sense of inquiry and capability for asking relevant/appropriate questions, problem, synthesising and articulating
3. **Analytical reasoning**: Ability to evaluate the reliability and relevance of evidence; identify logical flaws and holes in the arguments of others
4. **Critical thinking**: Capability to apply analytic thought to a body of knowledge
5. **Problem solving**: Capacity to extrapolate from what one has learned and apply their competencies to solve different kinds of non-familiar problems
6. **Communication Skills**: Ability to express thoughts and ideas effectively in writing and orally
7. **Information/digital literacy**: Capability to use ICT in a variety of learning situations; demonstrate an ability to access, evaluate, and use a variety of relevant information sources; and use appropriate software for analysis of data.
8. **Self-directed learning**: Ability to work independently, identify appropriate resources required for a project, and manage a project through to completion.
9. **Cooperation/Teamwork**: Ability to work effectively and respectfully with diverse teams
10. **Scientific reasoning**: Ability to analyse, interpret and draw conclusions from quantitative/qualitative data; and critically evaluate ideas, evidence and experiences from an open-minded and reasoned perspective
11. **Reflective thinking**: Critical sensibility to lived experiences, with self-awareness and reflexivity of both self and society.
12. **Multicultural competence**: Possess knowledge of the values and beliefs of multiple cultures and a global perspective

13. **Moral and ethical awareness/reasoning**: Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work
14. **Leadership readiness/qualities**: Capability for mapping out the tasks of a team or an organization, setting direction, formulating an inspiring vision, building a team who can help achieve the vision, motivating and inspiring team members to engage with that vision, and using management skills to guide people to the right destination, smoothly and efficiently.
15. **Lifelong learning**: Ability to acquire knowledge and skills, including 'learning how to learn', that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of the work place through knowledge/skill development.

### 1.3.2 Programme Outcomes (POs) for Postgraduate programme

POs are statements that describe what the students graduating from any of the educational programmes should able to do. They are the indicators of what knowledge, skills and attitudes a graduate should have at the time of graduation.

1. **In-depth knowledge**: Acquire a systematic, extensive and coherent knowledge and understanding of their academic discipline as a whole and its applications, and links to related disciplinary areas/subjects of study; demonstrate a critical understanding of the latest developments in the subject, and an ability to use established techniques of analysis and enquiry within the subject domain.
2. **Understanding Theories**: Apply, assess and debate the major schools of thought and theories, principles and concepts, and emerging issues in the academic discipline.
3. **Analytical and critical thinking**: Demonstrate independent learning, analytical and critical thinking of a wide range of ideas and complex problems and issues.
4. **Critical assessment**: Use knowledge, understanding and skills for the critical assessment of a wide range of ideas and complex problems and issues relating to the chosen field of study.
5. **Research and Innovation**: Demonstrate comprehensive knowledge about current research and innovation, and acquire techniques and skills required for identifying problems and issues to produce a well-researched written work that engages with various sources employing a range of disciplinary techniques and scientific methods applicable.
6. **Interdisciplinary Perspective:** Commitment to intellectual openness and developing understanding beyond subject domains; answering questions, solving problems and addressing contemporary social issues by synthesizing knowledge from multiple disciplines.
7. **Communication Competence:** Demonstrate effective oral and written communicative skills to covey disciplinary knowledge and to communicate the results of studies undertaken in an academic field accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s) of study
8. **Career development**: Demonstrate subject-related knowledge and skills that are relevant to academic, professional, soft skills and employability required for higher education and placements.
9. **Teamwork**: Work in teams with enhanced interpersonal skills and leadership qualities.

10. **Commitment to the society and to the Nation:** Recognise the importance of social, environmental, human and other critical issues faced by humanity at the local, national and international level; appreciate the pluralistic national culture and the importance of national integration.

### 1.3.3 Programme Specific Outcomes (PSOs) in Mathematics

Programme specific outcomes include subject-specific skills and generic skills, including transferable global skills and competencies, the achievement of which the students of a specific programme of study should be able to demonstrate for the award of the degree. The programme specific outcomes would also focus on knowledge and skills that prepare students for further study, employment. They help ensure comparability of learning levels and academic standards across universities and provide a broad picture of the level of competence of graduates of a given programme of study. The attainment of PSOs for a programme is computed by accumulating PSO attainment in all the courses comprising the programme.

1. **Basic Concept**: Ability to interpret and analyze various concepts and theories
2. **Understanding real life application**: An understanding application of various methods and apply in real life problem.
3. **Research and Innovation**: Use of knowledge to identify a wide range of contemporary problems and issues and acquire research skills to produce a well-researched written work using geographical research tools.
4. **Critical thinking**: Able to identify critical problems.

### 1.3.4 Course Level Learning Outcome Matrix

Course Level Learning Outcomes Matrix – **Core Course**

| **Programme Specific Outcomes** | 701 | 702 | 703 | 704 | 705 | 801 | 802 | 803 | 804 | 805 | 901 | 902 | 903 | 904 | 1001 | 1002 | 1004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Basic Concepts | x | x | x | x | X | X | x | x | x | x | x | x | x | x | x | x | |
| Understand real life application | x | x | x | x | X | X | x | x | X | x | x | x | x | x | x | X | |
| Research and innovations | x | x | x | x | X | X | x | x | X | X | x | x | x | x | x | X | x |
| Critical thinking | x | x | x | x | X | X | x | x | x | x | x | x | x | x | x | x | x |

Course Level Learning Outcomes Matrix – **Elective papers**

| **Programme Specific Outcomes** | 905 | 1003 |
|---|---|---|
| Basic Concepts | x | X |
| Understand real life application | x | x |
| Research and innovations | x | x |
| Critical thinking | x | X |

## 1.4 Teaching-learning process

The department of Mathematics, Cotton University has student-centric teaching-learning pedagogies to enhance the learning experiences of the students. All classroom lectures are interactive in nature, allowing the students to have meaningful discussions and question and answer sessions. Apart from the physical classes, lectures are also held in online mode where students can have doubt clearing and discussions with the teachers. Most of the teachers use ICT facilities with power-point presentations, e-learning platforms and other innovative e-content platforms for student-centric learning methods.

The Department has adopted participative teaching-learning practices, which includes seminars, presentations and group discussions. These participative teaching-learning practices are included in the curricula of almost all the courses. Apart from these, exposure visits, special lectures by invited experts, workshops, and National/International seminars are held to augment knowledge, encourage innovative ideas and expose the students to global academic and research advancement.

The short-term projects, research projects, assignments and field works, which are the integral components of all the courses, enable the students to solve practical problems. Students are also being engaged in sample surveys, data collection and analysis works of the in-house and external research projects for acquiring experiential learning. The laboratories of the department offer hands-on learning experiences to the students.

## 1.5 Assessment methods

A variety of assessment methods that are appropriate to the discipline are used to assess progress towards the course/programme learning outcomes. Priority is accorded to formative assessment. Progress towards achievement of learning outcomes is assessed using the following: closed-book examinations; problem-based assignments; practical assignment; laboratory reports; individual project reports (case-study reports); team project reports; oral presentations, including seminar presentation; viva voce interviews; computerised testing and any other pedagogic approaches as per the context.

## PART II
## Structure of Post-Graduate programme in Mathematics

### I. Outline of the courses under Choice Based Credit System:

| Semester | Course | Credit (L+T+P) | |
|---|---|---|---|
| **I** | MTH701C: Analysis | **3+1+0** | |
| | MTH702C: Linear Algebra | **3+1+0** | |
| | MTH703C: Mathematical Methods | **3+1+0** | |
| | MTH704C: Mechanics | **3+1+0** | |
| | MTH705L: Computer Programming with C | **2+0+2** | |
| **II** | MTH801C: Topology | **3+1+0** | |
| | MTH802C: Abstract Algebra | **3+1+0** | |
| | MTH803C: Differential Equations | **3+1+0** | |
| | MTH804C: Complex Function Theory | **3+1+0** | |
| | MTH805L: Numerical Analysis and Computation | **2+0+2** | |
| **III** | MTH901C: Functional Analysis | **3+1+0** | |
| | MTH902C: Tensor and Hydrodynamics | **3+1+0** | |
| | MTH903C: Graph Theory and Calculus of Variation | **3+1+0** | |
| | MTH904SP.. (SPECIAL I) | **4+1+0** | |
| | MTH905OE..(OPEN ELECTIVE I) | **3+1+0** | |
| **IV** | MTH1001C: Discrete Mathematics | **3+1+0** | |
| | MTH1002SP..(SPECIAL II) | **4+1+0** | |
| | MTH1003OE..(OPEN ELECTIVE II) | **3+1+0** | |
| | MTH1004 DPW (PROJECT) | **6** | |

| | |
|---|---|
| **Special I** | (a) Ring Theory |
| | (b) Fields and Galois Theory |
| | (c) Algebraic Topology |
| | (d) Space Dynamics |
| | (e) Theory of Relativity |
| | (f) Advanced Group Theory |
| | (g) Introduction to Lie Algebras |
| **Special II** | (a) Number Theory And Cryptography |
| | (b) Fluid Dynamics |
| | (c) Finite Element Method |
| | (d) Algebraic Number Theory |
| | (e)Fuzzy Sets and Applications |
| | (f) Dynamical Systems |
| | (g) Commutative Algebra |
| **OPE 1** | (a) Continuum Mechanics |
| | (b) Operation Research |
| | (c) Application of Mathematics in Finance |
| | (d) Optimization Technique |
| | (e) Mathematical Modelling |
| **OPE II** | (a) Combinatorics |
| | (b) Differential Geometry |
| | (c) Scientific Computing |
| | (d) Industrial Mathematics |
| | (e) Biomechanics |

## SEMESTER – 1

### MTH701C: Analysis

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept of uniform convergence of sequence and series of functions, power series, Fourier series, directional derivatives, total derivatives in terms of partial derivative, implicit function, bounded variations, total variations, Reimann-Stieltjes integral, vector valued function, rectifiable curves, set functions, construction of Lebesgue measure, measure space, measurable functions, simple functions, function of class L2.

**Course Learning Outcomes:** This course will enable the students to:

1. Use of uniform convergence of sequence and series of functions
2. Use of Stone-Weirstrass Theorem to solve problems.
3. Use of exponential and logarithmic functions, trigonometric functions, Fourier series to solve problems
4. Apply the Lagrange's multipliers method in extremum problem
5. Use of bounded variations, Reimann-Stieltjes integral and there applications
6. Use of Lebesgue measure, measure space, measurable functions, simple functions

Unit - I

Sequence and series of functions, Uniform Convergence and continuity, Uniform Convergence and Differentiation and integration, Equicontinuouss families of functions, The Stone-Weirstrass Theorem, Some special functions: Power series, The Exponential and Logarithmic functions, The Trigonometric functions, Fourier series.

Unit - II

Directional derivatives and its continuity, The total derivatives in terms of partial derivative, Matrix of Linear functions, Jacobian Matrix, Chain Rules, Mean-Value Theorem, Sufficient conditions of differentiability, Sufficient condition for equality of mixed partial derivatives, Taylor’s theorem in $R^n$, Implicit function, Inverse function Theorem, Implicit function Theorem, Extremum problems and Extremum problem with Lagrange's multipliers.

Unit - III

Bounded Variations, Total Variations, Continuous Functions of Bounded Variations.

Reimann-Stieltjes Integral: Definition and existence, Properties, Vector valued function, Integration of Vector valued function, rectifiable curves.

Unit - IV

Set functions, Construction of Lebesgue measure, Measure space, Measurable functions, Simple functions, Integration: Lebesgue Monotone Convergence theorem, Lebesgue dominated convergence theorem, Integration of complex valued function, Function of Class L2, Reisz-Fischer Theorem.

**Books Recommended**

1. W. Rudin, Principles of Mathematical Analysis($3^{rd}$ Edition), McGraw Hill Education2017. [for Unit I, III,IV]
2. T. M. Apostol, Mathematical Analysis,Narosa, 2002. [for Unit II]

**Books for Reference**

1. R. G. Bartle and D. R. Sherbert , Introduction to Real Analysis (3rd edition) , John Wiley & Sons, Inc., New York, 2000.
2. H.H. Sohrab, Basic Real Analysis($2^{nd}$ Edition ),Birkhäuser,2003

## MTH702C: Linear Algebra

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs.

**Course Objectives:** The primary objective of this course is to introduce the basic concept of matrix of a linear operator, eigen values and eigen vectors, diagonalization, Jordan canonical form, Determinant, properties of determinants, Cramer's rule, Bilinear form, symmetric form, Hermitian form, orthogonality, modules, diagonalization of integer matrices, Noetherian rings, structure of Abelian groups.

**Course Learning Outcomes:** This course will enable the students to:

1. Learn about eigen values and eigen vectors of a linear operator and a matrix, learn about the diagonalization of a matrix and find the Jordan canonical form of a matrix.
2. Learn about determinant and its properties.
3. Learn about Bilinear form and Hermitian form and orthogonality, construction of orthogonal basis of a vector space.
4. Learn about module and structure of Abelian group, digonalized form of an integer matrix.

Unit– I

The dimension formula, matrix of a linear operator, eigen values and eigen vectors, characteristic polynomial, orthogonal matrices and rotations, diagonalization, Jordan canonical form.

Unit– II

Determinant functions, permutations and the uniqueness of determinants, additional properties of determinants, Cramer's rule.

Unit– III

Bilinear form, symmetric form, Hermitian form, orthogonality, Euclidean spaces and Hermitian spaces, spectral theorem, conics and quadrics, skew-symmetric form.

Unit– IV

Linear algebra in ring: modules, free modules, diagonalizing integer matrices, generators and relations, Noetherian rings, structure of Abelian groups, applications to linear operators.

**Books recommended:**


1. M. Artin, Algebra(2nd edition),PHI Learning, 2011
2. K.Hoffman &R.Kunze, Linear Algebra(2nd edition), Prentice Hall India ,2015


**Books for Reference**


1. G. Strang , Linear Algebra and Its Applications, Cengage Learning, 2007
2. P.K.Saikia , Linear Algebra, Pearson, 2009


## MTH703C: Mathematical Methods

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs.

**Course Objectives:** The objective of this course is to study the integral equations, Fourier series, Fourier integral, Fourier integral transform and Laplace transform.

**Course Learning Outcomes:** This course will enable the students to:

1. Solve the integral equations.
2. Find the Fourier series for periodic functions and Fourier integrals for non-periodic functions.
3. Use Fourier integral transforms and Laplace transforms to solve differential equations and in evaluation of definite integrals.

Unit – I

Integral Equation: Definition of integral Equation and classifications, reduction of ordinary differential equations into integral equations. Fredholm integral equations with separable kernels, Eigen values and Eigen functions, method of successive approximation. Iterative scheme for Fedholm integral equations of second kind.

Unit - II

Volterra integral equations of second kind, resolvent kernel of Volterra equation and its results, application of iterative scheme to Volterra equation of the second kind. Convolution type kernels.

Unit - III

Introduction to Fourier series; Fourier series for periodic functions; Dirichlet's conditions; Fourier series of even and odd functions; Half range Fourier sine series and cosine series. Fourier integral.

Fourier Integral transform. Properties of Fourier transform, Fourier sine and cosine transforms, application of Fourier transform to ordinary and partial differential equations of initial and boundary value problems. Evaluation of definite integrals.

Unit - IV

Laplace Transform : Basic properties of Laplace transform, Convolution theorem and properties of convolution, inverse Laplace transform, application of Laplace transform to solution of ordinary and partial differential equations of initial and boundary value problems. Evaluation of definite integrals.

**Books Recommendeds**

1. R.P. Kanwal, Linear Integral Equations:Theory and Techniques, Academic Press, New York, 1971
2. F. B. Hilderbrand, Methods of Applied Mathematics, Dover Publications Inc., 1992.
3. I.N. Sneddon, Fourier Transforms, Dover Publications Inc., 2003
4. M.R. Spiegel ,Theory and problems of Laplace Transform, McGraw-Hill Education, 1965
5. F. G. Tricomi, Integral Equations, Dover Publications Inc, 1985.
6. Lokenath Debnath, Dambaru Bhatta, Integral Transforms and Their Applications, Chapman and Hall/CRC,, 2014

**Books for Reference**

1. S. G. Mikhlin ,Linear Integral Equations (Translated from Russia), Hindustan Book Agency, 1960

## MTH704C: Mechanics

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs.

**Course Objectives:** The objective of this course is to study motion in two dimensions, motion in three dimensions, motion of a rigid body under impulsive forces, motion of a rigid body about a fixed point, Euler's Geometrical and dynamical systems, motion under no external pressure, General coordinates, Lagrange's equation of motion for finite and impulsive forces in holonomic systems, Hamilton's principle, and principle of least action etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Familiarize with motion in two dimensions (under finite forces). motion in two dimensions (under impulsive forces).
2. Understand motion in three dimensions, velocity and acceleration in cylindrical and spherical polar coordinates.
3. Apply principle of virtual work in impulsive motions.
4. Familiarize with Motion under no external pressure.
5. Understand general coordinates.
6. Apply Hamilton's principle, and principle of least action.

Unit - I

Motion in two dimensions (under finite forces). Motion in two dimensions (under impulsive forces).

Unit - II

Motion in three dimensions, velocity and acceleration in cylindrical and spherical polar coordinates, motion on cylindrical, spherical and conical surfaces.

Unit - III

Motion of a rigid body under impulsive forces; Application of Principle of virtual work in impulsive motions; Carnot's theorem; Kelvin's theorem and Bertrand's theorem.

Unit - IV

Motion of a rigid body about a fixed point; Euler's Geometrical and Dynamical systems; Motion under no external pressure.

Unit – V

General coordinates, Lagrange's equation of motion for finite and impulsive forces in holonomic systems. Case of conservative forces and theory of small oscillation.

Unit - VI

Hamilton's equation of motion, Variational methods. Hamilton's principle, and principle of least action.

**Books Recommended**

1. M. R. Spiegel,Theoretical Mechanics, McGraw Hill Education, 2017
2. H. Goldstein, C. P. Poole, J. L. Safko, Classical Mechanics(3rd edition), Pearson,2001
3. S. L. Loney, An Elementary Treatise on Dynamics of a Particle and of Rigid Bodies, New Age International Private Limited, 2016
4. F. Chorlton, Text Books of Dynamics, CBS Publisher, 2002

**Books for Reference**

1. M. Rahman, Rigid Dynamics, New central book agency pvt. Ltd, 2011.

**MTH705L: Computer Programming with C**

**Total Marks: 100** (Theory: 35, Practical: 35, Internal Assessment: 30)
**Workload:** 2 Lectures, 2 practical (per week) **Credits:** 4 (2+0+2)
**Duration:** 14 Weeks (84 Hrs.) **Examination: 2** Hrs. (Theory) and **2** Hrs. (Practical)

**Course Objectives:**

The main objective of this course is to advance learning of C language. A brash up of the basic concepts the C language, loops, the concept of functions, user defined functions, pointers, one dimensional and higher dimensional arrays, applications of arrays, user defined data types, shorting and searching of numbers, string handling functions, applications of strings, uses of files.
Programming of some numerical problems in windows operating system and Linux operating system.

**Course Learning Outcomes:** This course will enable the students to:

1. Operations on matrices
2. Sorting of numbers and strings.
3. Searching key elements from sequences.
4. Sorting and searching using Files.
5. Subtraction and multiplication of matrices.
6. Solution of transcendental equation.
7. Interpolation by Lagrange methods, Newton forward and backward methods

Unit-I

Revision of fundamentals of C: Data types in C, variables in C, input output statements, constant declaration, arithmetic operators in C, conditional statements, loops. Break statement, the continue statement, the go-to statement. Functions and Recursive functions. Pointers.

Unit-II

Arrays: Arrays, declaration of one dimensional arrays, two dimensional arrays. User defined data types: structures, array of structures, unions, enumerated data type.

Unit-III

Searching and Sorting: Bubble sort, selection sort, insertion sort, linear search and binary search.

Unit-IV

Character array and strings: Arithmetic operations on characters, String-handling functions. Files in C: Defining and opening a file, closing a file. Input/Output operations on files.

**Lab Work**

Arranging given set of numbers in increasing/decreasing order , Sieve method for primality test, generation of twin primes, solution of congruence using complete residue system, addition, subtraction and multiplication of matrices, transpose, determinant, writing a given number in words using function, operations with strings and sorting, arranging a set of names in alphabetical order, searching a pattern in a given text and replacing every occurrence of it with another given string, solution of transcendental equation (Bisection method, Newton-Raphson method, Regula-Falsi method), Interpolation (Newton forward and backward, Lagrange methods).

**Books Recommended**

1. E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill, 2004

2. T. Jeyapoovan, A first course in programming with C, Vikas Publishing House,2004

**Books for Reference**

1. Y. P. Kanetkar, Let us C , BPB Publication, 2001.

2. M. G.Venkateshmurthy, Programming Techniques through C, Pearson Education, 2002.

3.V. Rajaraman, Fundamentals of Computers, Prentice Hall of India, New Delhi, 2002.

---------------------------------------------------------------------------------------------

**SEMESTER-2**

## MTH801C: Topology

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept oforder relations, dictionary order, wellordered set, minimal uncountable well ordered set, order topology, product topology, continuity and related concepts, product topology and box topology; Metric topology, Quotient topology, Connected spaces, local path-connectedness etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Familiarize with order relations, dictionary order, well ordered set, product topology.
2. Understand continuity and related concepts
3. Familiarize with Lindeloff spaces, separable spaces, separation axioms
4. Understand Finite product of compact spaces; Compact subspaces of the real space.

Unit-I

Order relations, dictionary order, well ordered set, minimal uncountable well ordered set SΩ, Definition and examples of topological spaces; basis and sub basis; order topology; product topology on XxY, subspace topology; Closed sets and limit points, Hausdorff space.

Unit - II

Continuity and related concepts; Homeomorphism; Pasting lemma, Product topology and Box topology; Metric topology, Quotient topology.

Unit - III

Connected spaces, Connected subspace of the real space; component, path component; local connectedness, local path-connectedness.

Unit - IV

Compact spaces; Tube lemma; Finite product of compact spaces; Compact subspaces of the real space; limit point compact and sequentially compact spaces; locally compact spaces; one point compactification; statement of Tychonoff's theorem.

Unit - V

Countability axioms; Lindeloff spaces and separable spaces. Separation axioms; Normal Spaces; Urysohn's lemma; statement of Urysohn's metrization theorem. Tietze's extension theorem.

**Books Recommended**

1. J. R. Munkres, Topology:a first course , Prentice-Hall of India Ltd., New Delhi, 2000
2. J. L. Kelley, General Topology, Springer Verlag, New York, 1990.

**Books for Reference**

1. K.D. Joshi, An introduction to general topology (2nd edition), Wiley Eastern Ltd., New Delhi, 2002.
2. J. Dugundji, General Topology, Universal Book Stall, New Delhi, 1990.

**MTH802C: Abstract Algebra**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The objective of this course is to study Group action and permutations representations, Cayley's theorem, class equation, the fundamental theorem of finitely generated abelian group, p-groups, solvable groups, polynomial rings over a field, Subfield and prime fields, extensions of fields.

**Course Learning Outcomes:** This course will enable the students to:

1. Familiarize with group action, groups acting on themselves by conjugation.
2. Understand direct products, the fundamental theorem of finitely generated abelian group, p-groups, solvable groups.
3. Familiarize with Eisenstien's criterion for irreducibility of $f(x) \in Z[x]$ over Q, roots of polynomials.
4. Familiarize with subfield and prime fields.

Unit -I

Group action and permutations representations, group acting on themselves by left multiplication-Cayley's theorem, groups acting on themselves by conjugation, class equation, automorphisms, theorems, simplicity of $A_n$.

Unit -II

Direct products, the fundamental theorem of finitely generated abelian group, group of small order, recognising direct products, semi-direct products, p-groups, solvable groups.

Unit -III

A brief review of polynomial rings over a field, reducible and irreducible polynomials, primitive polynomials, Gauss theorem for reducibility of $f(x) \in Z[x]$, Eisenstien's criterion for irreducibility of $f(x) \in Z[x]$ over Q, roots of polynomials, Finite fields of order 4,8,9 and 27 using irreducible polynomials over $Z_2$ and $Z_3$.

Unit -IV

Subfield and prime fields, extensions of fields, algebraic extension, splitting field.

**Books Recommended**

1.D.S.Dummit and R.M.Foote , Abstract Algebra( 3rd Edition), Wiley,2011

2. T. W. Hungerford , Abstract Algebra(3rd edition), Brooks/Cole,1996

3. N. Jacobson, Basic Algebra I (3rd edition) , Hindustan Publishing corporation, New Delhi, 2002.

**Books for Reference**

1. J. B. Fraleigh , A First Course in Abstract Algebra (4th edition), Narosa Publishing House, New Delhi, 2002.

2. J. A. Gallian, Contemporary Abstract Algebra (4th edition), Narosa Publishing House, New Delhi, 1999.

3. I. N. Herstein,Topics in Algebra, Wiley,2006

**MTH803C: Differential Equations**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The objective of this course is to study Initial Value Problems (IVP), second order differential equations and few methods to solve Partial Differential Equations (PDE).

**Course Learning Outcomes:** This course will enable the students to:

5. Solve IVP.
6. Solve elliptic, parabolic and hyperbolic differential equations.
7. Monge's method to solve non-linear PDEs.
8. Reducing the PDEs into its canonical forms.
9. Solve PDE by separation of variables method.

Unit-I

Initial value problems(IVP) for first order equations; Lipschitz condition, existence and uniqueness theorem for first order equations. Initial value problems for second order equations; existence theorem; uniqueness theorem; linear dependence and independence of solutions; Wronskian.

Unit-II

Partial Differential equations reducible to equations with constant coefficients. Second order PDE with variable coefficients. Characteristic curves of second order PDE. Monge's method of solution of non-linear PDE of second order. Reduction to canonical forms. Solutions of PDE of second order by the method of separation of variables.

Unit-III

Elliptic differential equations. Occurrence and detailed study of the Laplace and the Poisson equation. Maximum principle and applications, Green's functions and properties.

Unit-IV

Parabolic differential equations. Occurrence and detailed study of the heat equation. Maximum principle. Solutions of IVPs for heat conduction equation. Green's function for heat equation, Duhamel's principle.

Unit-V

Hyperbolic differential equations. Occurrence and detailed study of the wave equation. Solution of three dimensional wave equation. Method of descent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions.

**Books Recommended(s):**

1. E. A. Coddington, An Introduction to Ordinary Differential Equations ,Dover Publication, 1989

2. I.N. Sneddon, Partial Differential Equations ,McGraw-Hill, 1957

3. K.S.Rao, Introduction to partial differential equations ,Prentice Hall of India, New Delhi, 2006

**Reference Book(s):**

1. R. Haberman, Elementary Applied Partial Differential equations, Prentice-Hall, New Jersey, 1987

2.W.E. Willams, Partial Differential Equations ,Oxford University Press, 1980

3. W.A.Strauss, Partial Differential Equations: An Introduction ,John Wiley, 1992

**MTH804C: Complex Function Theory**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept of analytic function, conformal maps, mobius transformation,Riemann-Stieltjes integrals,power series representation of analytic functions, Cauchy's theorem and integral formula, homotopy, singularities,extended plane and stereographic projection, residues, contour integration, analytic continuation.

**Course Learning Outcomes:** This course will enable the students to:

1. Learn straight lines, half planes, circles in complex form
2. Use of cross ratio; symmetry and orientation principle.
3. Use and applications of analytic functions
4. Learn Cauchy's theorem and integral formula on open subset of C
5. Use of homotopy in Cauchy's theorem
6. Learn classification of singularities and its applications in Laurent series
7. Learn residues, contour integration and their applications.

Unit-I

Complex form of equations of straight lines, half planes, circles, etc., analytic (holomorphic) function as mappings; conformal maps; Mobius transformation; cross ratio; symmetry and orientation principle; examples of images of regions under elementary analytic function. branch of logarithm, Riemann-Stieltjes integrals.

Unit-II

Power series representation of analytic functions, zeros of analytic functions, maximum modulo theorem, Cauchy's theorem and integral formula on open subset of C, Unit-III

Homotopy, homotopic version of Cauchy's theorem, simple connectedness, counting zeros, open mapping theorem, Goursat's theorem, Classification of singularities, extended plane and stereographic projection, Laurent series.

Unit-IV

Residues, contour integration, argument principle, Rouche's theorem, maximum principle, Schwarz's lemma. Analytic continuation..

**Books Recommended**

1. J. H. Mathews, and R. W.Howell, Complex Analysis for Mathematics and Engineering,(3rd Edition), Narosa, 1998.
2. J. B.Conway, Functions of One Complex Variable(2nd Edition), Narosa Publishing House, 1994

**Books for Reference**

1. L. V. Ahlfors, Complex Analysis(3rd Edition) ,McGraw-Hill Publishing Company, New Delhi, 1979).
2. H.A. Priestly, Introduction to Complex Analysis (2nd Edition), Cambridge University Press, 2008
3. T. W. Gamelin, Complex Analysis, Springer, 2003.
4. R. Narasimhan, and Y. Nievergelt, Complex Analysis in One Variable(2nd Edition), Springer (India), New Delhi, 2004.
5. R. V. Churchill, Complex Variables and applications, McGraw-Hill, 1996.
6. S. Ponnusamy, and H. Silverman, Complex Variables and Applications, Birhkäuser, 2006.

## MTH805L: Numerical Analysis and Computation

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of systems of linear algebraic equations and their solutions, error analysis, rate of convergence, eigen value problem, solving ordnary differential equations, Finite difference methods for 2D and 3D elliptic boundary value problems.

**Course Learning Outcomes:** This course will enable the students to:

1. Apply Iterative method for matrix inversion.
2. Solving of eigen value problem by Jacobi's method, Given's method, Power method.

3. Apply Euler's method, Single step Methods, Taylor series method , Runge-Kutta's method to solve ordinary differential equations.
4. Apply Finite difference methods to solve 2D and 3D elliptic boundary value problems.

Unit -I

Systems of linear algebraic equations and their solutions: iterative methods; Gauss- Jacobi, Gauss-Seidel, successive over-relaxation iteration methods. Iterative method for matrix inversion; error analysis, rate of convergence.

Unit -II

The algebraic eigen value Problem: Solutions of eigen value problem by Jacobi's method, Given's method, Power method.

Unit -III

Ordinary differential equations: Euler's method, Single step Methods, Taylor series method, Runge-Kutta's method, multi-step methods, Milne-Simpson method; stability and convergence analysis.

Unit -IV

Finite difference methods for 2D and 3D elliptic boundary value problems (BVPs) and error analysis.

Lab work : C program / Matlab / Fortran

**Books Recommended**

1. C.F.Gerald &P.O.Wheatly, Applied Numerical Analysis(7$^{th}$ Edition), Pearson, 2004

2. W. W. Hager ,Applied Numerical Linear Algebra, Prentice Hall International Editions, 1988

3. J.C. Strickwerda, Finite Difference Schemes & Partial Differential Equations, SIAM publications, 2004.

**Reference Books**

1.M.K. Jain, S.R.K. Iyengar, R.K. Jain: Numerical Methods for Scientific and Engineering Computation, New Age,2014

2. K. W. Morton, & David Mayers, Numerical solution of partial differential equations, Cambridge University Press, 2005.

3. J.W.Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Springer Verlag, Berlin, 1998.

-----------------------------------------------------------------------------------------------

**SEMESTER-3**

**MTH901C: Functional Analysis**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept of topological algebraic structures namely normed linear spaces, Banach spaces, inner product spaces and Hilbert spaces. The classical $L_p$spaces, Holder's inequality, Minkowski's inequality, Riesz -Fisher theorem and Riesz representation theorem for bounded linear functional in $L_p$spaceare introduced.Also introduce the basic idea of continuous linear transformations between normed linear spaces, Hahn Banach theorem which allows extension of a bounded linear functional from a subspace of a normed space to the whole space. Embedding of normed linear space in its second conjugate space, weak and strong topologies, Open mapping theorem, Closed Graph theorem, uniform boundedness theorem are introduced. Also introduce orthogonal complement of a set, orthonormal set, complete orthonormal set, Bessel's inequality, Gram Schmidt orthogonalization process and adjoint operators. Normal and unitary operators, projections, spectrum of an operator and spectral theory for a normal operator on a finite dimensionalHilbert spaces are introduced.

**Course Learning Outcomes:** This course will enable the students to:

1. Have the knowledge of topological algebraic structures namely normed linear spaces, Banach spaces, inner product spaces and Hilbert spaces.
2. Understand the properties of operatorson Banach and Hilbert spaces.
3. Identify the duals of normed linear spaces and the orthogonal sets by applying some specific techniques.
4. Analyze the basic results associated to different types of convergence in normed linear spaces.
5. Evaluate the extension of a given functional with norms, orthogonal complement and examine separability, reflexivity of normed linear space.
6. Apply parallelogram law to determine whether a Banach space is an inner product space or not.
7. Evaluate spectrum of various operators on finite dimensional Hilbert spaces.

Unit -I

Normed linear space and its properties, Banach space, Lp space; Holder's inequality, Minkowski's inequality; convergence and completeness; Riesz-Fischer theorem, bounded linear functional on Lp spaces, Riesz representation theorem.

Unit -II

General Banach spaces – definition and examples; continuous linear transformations between normed linear spaces; Hahn-Banach theorem and its consequences.

Unit -III

Embedding of a normed linear space in its second conjugate space; strong and weak topologies; open mapping theorem; closed graph theorem; uniform boundedness theorem; conjugate of an operator.

Unit -IV

Inner product space and its properties, Hilbert's space, orthogonal complements, orthonormal set, Bessel's inequalities, complete orthonormal sets, Gram-Schmidt orthogonalization process, self adjoint operators.

Unit -V

Normal and Unitary operators, projections, spectrum of an operator, spectral theorem for a
normal operator on a finite dimensional Hilbert space.

**Books Recommended**

1. H. L. Royden, Real Analysis (4th edition), Macmillan Publishing co. inc, New York, 1999.
2. G. F. Simmons, Introduction to Topology and Modern Analysis (4th edition), McGraw Hill Education, 2004.

**Books for Reference**

1. W. Rudin, Functional Analysis , McGraw Hill Education, 2017
2. B. V. Limaye, Functional Analysis, Willy Eastern Ltd., 1991.
3. C.Goffman and G. Pedrick, First course in Functional Analysis, Prentice-Hall of India Pvt. Ltd, New Delhi, 1974.

**MTH902C: Tensor and Hydrodynamics**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:**

**Tensor:** This course is design to introduce the basic concept tensor and its utilities. Covariant and contravariant tensors, Algebraic operations on tensors, Christoffel's brackets and their properties, Riemannian metric. Covariant derivatives of first and second order tensors.

**Hydrodynamics**

The objective of the course is to learn the basic concept of the fluids and their classifications.

Eulerian and Lagrangian approach of description. Mathematical formulations of conservation of mass conservation of momentum, and Conservation of energy. Irrotational motion and circulation, two dimensional, Complex potential.

**Course Learning Outcomes:** This course will enable the students to:

1. Transformation laws of covariant and contravariant tensors
2. Algebraic operations on tensors, Quotient law, group property of tensors.
3. Transformation laws of Christoffel brackets.
4. Covariant derivatives of tensors
5. Derivation of continuity equation, Euler's equation and energy equation
6. Irrotational motion, Kelvin's circulation theorem,
7. Complex potential, sources, sinks, doublets

**Tensor**

Unit -I

Transformation laws of covariant and contravariant tensors, Mixed tensor, Rank of tensors, symmetric and anti-symmetric tensors and related theorems, Algebraic operations on tensors, contraction, Inner and outer product of tensors, Quotient law, group property of tensors, Christoffel's brackets of $1^{st}$ first and second kinds, their properties, Riemannian metric Definitions of metric tensors, Transformation laws of Christoffel brackets.

Unit -II

Covariant derivatives of tensors $A_i$ , $A^i$, $A_{ij}$, $A^{ij}$ and $A^i_j$ , Generalizations, Covariant derivatives of metric tensors and scalar invariant function, Application in problems. Angle between two vectors, Curl, grad, divergence of vectors. Laplacian in tensor form.

**Hydrodynamics**

Unit -III

Classification of fluids, the continuum model, Eulerian and Lagrangian approach of description. Differentiation following fluid motion. Irrotational flow, vorticity vector, Streamlines, pathlines, streak lines of the particles.
Conservation of mass leading to equation of continuity. (Euler's form.) Conservation of momentum and its mathematical formulation: Euler's form. Conservation of energy and its mathematical formulation. Lagrange's hydrodynamical equations. Integration of Euler's equations of motion. Bernoulli's equation, steady motion under conservative body force.

Unit -IV

Theory of irrotational motion: Flow and circulation, Stokes theorem, Kelvin's circulation theorem, Kelvin's minimum energy theorem, potential theorems.
Stream function, Some two-dimensional irrotational flows, incompressible fluids. Complex potential. Sources, sinks, doublets, complex potential due to source.

**Books Recommendeds:**

1.F.Chorlton, Textbook of Fluid Dynamics, CBS Publishers, Delhi,2004

2. L.M.Milne-Thomson: Theoretical Hydrodynamics(5th ed. edition), Dover Publications, 2013

3. C. E. Weatherburn: An Introduction to Riemannian Geometry and Tensor Calculus, Cambridge University Press, 2008

**Reference Books**:

1. A. N. Das, Vector Analysis- Introduction to Tensor Analysis, U.N. Dhur and Sons Pvt. Ltd., 1932

2. P.K. Kundu and I.M. Cohen, Fluid Mechanics, Academic Press, 2005.

**MTH903C: Graph Theory and Calculus of Variation**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the concept of undirected graph, operation and connectedness of graph, different types of graphs, tree, center and centroid, independent cycles and co cycles, Connectivity and traversability, planarity and colorability, Calculus of Variation with single independent variable and multiple variables

**Course Learning Outcomes:** This course will enable the students to:

1. Learn and apply the connectedness of graph
2. Learn and apply the different types of operations of graph

3. Understandtree and its significance and applications in graph theory
4. Have the knowledge ofpoint connectivity and line connectivity and their applications
5. Applications of Eulerian and Hamiltonian graph
6. Learn and apply the Kuratowski's theorem in planar graph
7. Learn and apply the point coloring and chromatic number
8. Apply the Euler's equation in calculus of variation
9. Apply the variational problem of different forms
10. Learn isoperimetric problems and their applications

**Graph Theory**

Unit-I

Graphs: Vertices of graphs, walks and connectedness, degrees, operations on graphs, blocks, cut-points, bridges and blocks, block graphs and cut-point graphs.

Trees: Elementary properties of trees, centers and centroids, block-cut point trees, independent cycles and co cycles.

Unit-II

Connectivity and traversability: Connectivity and line connectivity, Menger's theorems, Eulerian graph, Hamiltonian graphs.

Unit-III

Planarity and Coloring: Planar graphs, outer planar graphs, Kuratowski's theorem, dual graphs, chromatic number, five color theorem.

**Calculus of Variation**

Unit -IV

Calculus of Variation with one independent variable:Basic ideas of calculus of variation, Euler's equation with fixed boundary of the functional

$$I[y(x)] = \int_a^b f(x, y, y')dx$$

containing only the first order derivative of the only dependent variable with respect to one independent variable. Variational problems with functionals having higher order derivatives of the only dependent variable, applications.

Unit -V

Calculus of Variation with several independent variables: Variational problems with functionals dependent on functions of several independent variables having first order derivatives. Variational problems in parametric form, variational problems with subsidiary condition (simple case only), Isoperimetric problems, Applications.

**Books Recommended**

1.F. Harary, Graph theory, Narosa Publishing House, New Delhi, 1988.

2.A.S. Gupta, Calculus of variation with Applications,Prentice Hall of India (1999)

**Books for Reference**

1. R. Balakrishnan and K. Renganathan, A textbook of Graph theory, Springer, 2000
2. B. Bollobas, Modern Graph Theory, Springer, 2002
3. G. Chartrand, L. Lesniak, Graphs & digraphs( Fourth edition), Chapman & Hall/CRC, 2005.
4. R. J. Wilson, Introduction to Graph Theory (5th Edition), Prentice Hall, 2010

**SPECIAL 1:**

**(a) Ring Theory**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The main objective of this course is to study ring theory in more general set-up with some basic concepts of rings in particular matrix rings and polynomial rings ; ideals and direct products of rings; fields and division rings; idempotent and nilpotent elements in a ring; basic concepts modules and submodules ; Direct sums and direct products of modules, external and internal direct sums, Isomorphism theorems; exact sequences; the group of homomorphisms and its properties relative to exact sequences; Zorn's lemma; free modules and projective modules; torsion free and torsion modules over commutative domains; exact sequences and projectivity, Injective modules, injectivity and divisibility over domains; exact sequences and injectivity; Baer's theorem and its elementary applications; simple modules, semi-simple modules ; Schur's lemma.

**Course Learning Outcome:** On successful completion of the course students are expected to

**1:** Acquire knowledge on basic concepts of rings in particular matrix rings and polynomial rings, ideals and direct products of rings; fields and division rings; idempotent and nilpotent elements in a ring.

**2**: Acquire knowledge of exact sequences; the group of homomorphisms and its properties relative to exact sequences.
**3**: Acquire knowledge of structure theories of modules; free modules and projective modules; torsion free and torsion modules over commutative domains; exact sequences and projectivity.

**4:** Acquire knowledge of Injective modules, injectivity and divisibility over domains; exact sequences; Baer's theorem and its elementary applications; simple modules, semi-simple modules ; Schur's lemma

**5:**Acquire knowledge on equivalent conditions for semisimple modules; Wedderburn structure theorem ; characterization of semisimple rings via projective and injective modules.

Unit - I

Basic concepts of rings, modules, operations on ideals and sub-modules; matrix rings, polynomial rings; direct products of rings; fields and division rings; idempotent and nilpotent elements in a ring.

Unit - II

Isomorphism theorems; exact sequences; the group of homomorphisms and its properties relative to exact sequences.

Unit - III

Direct sums and direct products of modules, external and internal direct sums, direct summands; Zorn's lemma, every vector space has a basis; free modules and projective modules; torsion free and torsion modules over commutative domains; exact sequences and projectivity.

Unit - IV

Injective modules, injectivity and divisibility over domains; exact sequences and injectivity;

Baer's theorem and its elementary applications; simple modules, semi-simple modules (as per Bourbaki); Schur's lemma.

Unit - V

Equivalent conditions for semisimple modules; Wedderburn structure theorem (only statement); characterization of semisimple rings via projective and injective modules.

**Books Recommended**

1. I. S. Luthar and I.B.S. Passi, Algebra, Vol. 2: Rings, Narosa Publishing House, New Delhi, 1999.

2. I. T. Adamson, Elementary Rings and Modules, Oliver and Boyd, Edinburgh, 1995.

3. N. Jacobson, Basic Algebra II (3rd edition), Hindustan Publishing Corporation, New Delhi, 2002.

4. J. J. Rotman, Notes on Homological Algebra, Van nostrand, 1990.

**Books for Reference**

1. S. Lang, Algebra( Second Edition), Addison-Wesley, Massachusetts, 1984.

2. D.S.Dummit and R.M.Foote , Abstract Algebra( 3rd Edition), Wiley,2011

**(b) Fields and Galois Theory**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)

**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The main idea of Galois Theory is to associate a group viz: Galois group to a field extension. The prime objective of this course is to study fields and their various extensions such as normal, separable and inseparable extensions; the structure of field extensions in particular, cyclotomic and cyclic extensions; roots of irreducible polynomials in particular, the polynomials of degree 3 and 4.

**Course Learning Outcome :** On successful completion of the course students are expected to

**1:** Acquire knowledge about fields and their various extensions. In addition, students will learn fundamental theorem of Galois Theory that describes the structure of certain types of field extensions in contrast to groups.

**2:** Acquire knowledge of field extensions in particular, cyclotomic extensions, cyclic extensions, etc that play a vital role in applications of Galois Theory.

**3:** Acquire knowledge of the discriminate of polynomials, and are expected to learn how to determine the Galois group and the roots of irreducible polynomial of degree 3 and 4. Moreover, students will learn the concept of so-called solvability.

Unit-I

Fields and their extensions, automorphism, normal extension, separable and inseparable extensions, the fundamental theorem of Galois theory,

Unit-II

Finite field, cyclotomic extension, norm and trace, cyclic extension,

Unit-III

Discriminant, polynomials of degree 3 and 4, solvability by radicals.

**Books Recommended**

1. P.Morandi, Field and Galois theory, Springer-Verlag, 1996

**Books for Reference**

1. P.M. Cohn, Basic Algebra,Springer International Edition, 2003.
2. I. Stewart, Galois Theory, Chapman and Hall, 1973
3. E. Artin, Galois Theory,  Dover Publications,1997
4. D.S.Dummit and R.M.Foote , Abstract  Algebra( 3rd Edition), Wiley,2011

**(c) Algebraic Topology**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The main idea of algebraic topology is to consider two spaces to be equivalent if they have "the same shape" in the sense that is much broader than homomorphism. Algebraic topology assigns discrete algebraic invariants to topological spaces and continuous maps. More narrowly, one wants the algebra to be invariant with respect to continuous deformation of the topology. The main objective of the study homotopy of paths; fundamental group of topological spaces and their properties; the method of computation of fundamental groups; Brower's fixed point theorem and its applications; Frobenius theorem on eigenvalues of 3 x 3 matrices, covering spaces and lifting properties; the concept of homologies and their calculation in case of S^{n}(n>1)

**Course Learning Outcome:** On successful completion of the course students are expected to

**1:** Acquire knowledge of homotopy, fundamental group of topological spaces and their properties so as to connect topological concepts with algebraic concepts.

**2:** Acquire knowledge of the method of computing the fundamental groups by Van Kampen's theorem. In addition to it, students are expected to learn Brouwer's fixed point theorem; fundamental theorem of algebra; vector fields and Frobenius theorem on eigenvalues of 3 x 3 matrices.

**3:** Acquire knowledge of covering spaces and lifting properties, and their criterions

**4:** Acquire Knowledge of homologies in particular, Simplicial and singular homology, reduced homology, etc, lifting theorems and their criterions

**5:** Acquired knowledge of Calculations of homology of $S^n$. In addition, students are expected to learn Brouwer's fixed point theorem and its applications to spheres and vector fields; Meyer-Vietoris sequence and its application.

Unit – I

Homotopy of paths, fundamental group of a topological space, fundamental group functor, homotopy of maps of topological spaces; homotopy equivalence; contractible and simply connected spaces; fundamental group of $S^1$, $S^1$ x $S^1$ etc.; degree of maps of $S^1$.

Unit – II

Calculation of fundamental groups of n (n > 1) using Van Kampen's theorem (special case); fundamental group of a topological group; Brouwer's fixed point theorem; fundamental theorem of algebra; vector fields, Frobenius theorem on eigenvalues of 3 x 3 matrices.

Unit – III

Covering spaces, unique lifting theorem, path-lifting theorem, covering homotopy theorem, applications; criterion of lifting of maps in terms of fundamental groups; universal coverings and its existence; special cases of manifolds and topological groups.

Unit – IV

Simplicial and singular homology, reduced homology, Eilenberg-Steenrod axioms (without proof), relation between Π1 and H1; relative homology.

Unit – V

Calculations of homology of $S^n$; Brouwer's fixed point theorem for $f : E^n \rightarrow E^n$ $(n > 2)$ and its applications to spheres and vector fields; Meyer-Vietoris sequence and its application.

**Books Recommended**

1. J. R. Munkres, Topology, a first course , Prentice-Hall of India Ltd., New Delhi, 2000.

2.M. J. Greenberg and J. R. Harper, Algebraic topology, a first course (2nd edition), Addison-Wesley Publishing co., 1997.

3.A. Hatcher, Algebraic Topology , Cambridge University Press, 2002.

**Books for Reference**

1.E. H. Spanier, Algebraic Topology (2nd edition) , Springer-Verlag, New York, 2000.

2.J. J. Rotman, An Introduction to Algebraic Topology, Graduate Text in Mathematics, No. 119, Springer, New york, 2004.

**(d) Space Dynamics**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:**The primary objective of this course is to introduce the basic concept of two body problem, Kepler's equation, solution by Hamilton- Jacobi Theory, Three Body problem, Restricted Three Body problem, stationary solutions of three body problem and its stability, The n-body problem, perturbation, Flight Mechanics etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand basic formulae of spherical triangle.
2. Understand the determination of Orbits: Laplace and Gauss methods.
3. Understand stationary solutions of three body problem and its stability.
4. Familiarize with the perturbing forces, perturbation of Keplerian elements of the moon by the sun.
5. Familiarize with analysis of a multi-stage rockets neglecting gravity, analysis of multi-stage rockets including gravity.

Unit-I

Basic formulae of spherical triangle – The Two Body problem.The motion of the centre of mass, the relative motion, Kepler's equation, Solution by Hamilton- Jacobi Theory. The determination of Orbits: Laplace and Gauss methods

Unit-II

The Three Body problem General Three Body problem, Restricted Three Body problem, Jacobi integral, Curves of zero velocity, stationary solutions of three body problem and its stability. The n-body problem: The motion of the centre of mass, classical integrals.

Unit- III

Perturbation: Osculating orbit, perturbing forces, Secular and Periodic perturbations, Lagrange's planetary equations in terms of perturbing forces. Motion of the moon – The perturbing forces, Perturbation of Keplerian elements of the moon by the sun.

Unit- IV

Flight Mechanics: Rocket performance in a vacuum, vertically ascending paths. Gravity twin trajectories, Multistage rocket in vacuum. Definitions pertinent to a single stage rocket, performance, limitations of a single stage rockets. Definitions pertinent to a multi-stage rockets, analysis of a multi-stage rockets neglecting gravity, analysis of multi-stage rockets including gravity.

**Books Recommended**

1. J.M.A. Danby, Fundamentals of Celestial Mechanics, The Macmillan Company, 1962.
2. E.Finlay-Freuhdlich, Celestial Mechanics , The Macmillan Company, 1958.
3. R. Deutsch,Orbital Dynamics of Space Vehicles, Prentice Hall Inc., New Jersey, 1963.

**Reference books**

1. T.E. Stern, An Introduction to Celestial Mechanics , Intersciences Publishers Inc,1960
2. A. Miele,Flight Mechanics Vol-I, Theory of Flight paths, Addison Wiley Publishing Company Inc.,1962

**(e) Theory of Relativity**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:**The primary objective of this course is to introduce the basic concept of special theory and general theory of relativity. Some important topic to be discussed are Lorentz transformations and consecutions of Lorentz transformations; relativistic mechanics; Minkowski space-time; equivalence of mass and energy, Geodesics, Riemann Christoffel Curvature tensors Riciitensor, Riemann Curvature, Energy-momentum tensors, crucial tests of general relativity and Cosmology.

**Course Learning Outcomes:** This course will enable the students to:

1. Inertial frames of reference, Lorentz transformations and their consequences
2. The concept of Minkowski space-time.
3. Derivation of the equation of geodesics
4. Riemann Christoffel Curvature tensors and their properties
5. Energy-momentum tensors for special and general relativity
6. Principle of equivalence, derivation of Einstein's equation and its solution.
7. Robertson-Walker metric and solution in unstatic model

Unit-I

The special theory of relativity: Inertial frames of reference; postulates of the special theory of relativity; Lorentz transformations; length contraction; time dilation; variation of mass; composition of velocities; relativistic mechanics; world events, world regions and light cone; Minkowski space-time; equivalence of mass and energy.

Unit –II

Energy-momentum tensors: the action principle; the electromagnetic theory; energy-momentum tensors (general); energy-momentum tensors (special cases); conservation laws.

Unit-III

General Theory of Relativity: introduction; principle of covariance; principle of equivalence; derivation of Einstein's equation; Newtonian approximation of Einstein's equations.

Unit –IV

Solution of Einstein's equation and crucial tests of general relativity: Schwarzschild solution; particle and photon orbits in Schwarzschild space-time; gravitational red shift; planetary motion; bending of light; radar echo delay. Einstein 's and de-Sitter models.

Unit –V

Cosmology: Robertson-Walker metric and solution in unstatic model, dynamical consequences and geometrical models.

**Books Recommended**

1. R.K. Pathria, The Theory of Relativity (2nd edition),Hindustan Publishing co.Delhi, 1994.

2. J.V. Narlikar, General Relativity & Cosmology (2nd edition) ,Macmillan co. of India Limited, 1988.

**Reference books:**

1. S. K. Srivastava and K. P. Sinha, Aspects of Gravitational Interactions, Nova Science Publishers Inc. Commack, New York, 1998.
2. W. Rindler, Essential Relativity , Springer-Verlag, 1977.
3. R.M. Wald,.General Relativity, University of Chicago Press, 1984.
4. R. Reshnick, Special theory of relativity, Wiley India Pvt. Ltd.,2010

**(f) Advanced Group Theory**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the concept of normal series, composition series,solvable groups, derived series, supersolvable groups, central series, nilpotent groups, Fitting subgroup, Jacobi identity, Frattini subgroup, extension of a group, semidirect products, free group, generators and relations, free products, free product with amalgamation.

**Course Learning Outcomes:** This course will enable the students to:

1. Learn and apply the Zessenhaus lemma, Schreier's refinement theorem, Jordan-Holder theorem.
2. Learn and apply the Hall's theorem and Schur's theorem
3. Learn and apply the three subgroup lemma and Burnside basis theorem
4. Applications of Fitting's lemma, Krull-Schmidt theorem
5. Learn and apply the Burnside normal complement theorem and its consequences
6. Learn and apply the Tietze's theorem, Covering complexes, Coset enumeration
7. Apply the Kurosh theorem.

Unit – I

Normal series, composition series, Zessenhaus lemma, Schreier's refinement theorem, Jordan-Holder theorem. Solvable groups, derived series, supersolvable groups, minimal normal subgroup, Hall's theorem, Hall subgroup, 26 p-complements, central series, nilpotent groups, Schur's theorem, Fitting subgroup, Jacobi identity, Three subgroup lemma, Frattini subgroup, Burnside basis theorem.

Unit – II

Fitting's lemma, Krull-Schmidt theorem, extension of a group, semidirect products, Schur-Zassenhaus lemma, Burnside normal complement theorem and its consequences.

Unit – III

Free group, generators and relations, Fundamental groups of complexes, Tietze's theorem, Covering complexes, Coset enumeration. Free products, Kurosh theorem, free product with amalgamation.

**Books Recommended**

1. J. J. Rotman. An introduction to the theory of groups, Springer-Verlag, New York, 1995.

**Books for Reference**

1. M. Suzuki, Group theory-I, Springer-Verlag, Berlin, 1982.
2. D. J. S. Robinson, A course in the theory of groups, Springer-Verlag, New York, 1996.
3. J. S. Rose, A course on group theory, Dover Publication, New york, 1994.
4. T. W. Hungerford, Algebra, Springer-Verlag, New York, 1981.

**(g) Introduction To Lie Algebras**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the concept ofLie algebras and Lie algebra homomorphisms, Semisimple Lie algebras - Lie's theorem, Cartan's criterion, Weyl's theorem, simple roots and the Weyl group, Cartan matrix of a root system, Dynkin diagrams, classification theorem etc.

**Course Learning Outcomes:** This course will enable the students to:

6. Familiarize with ofLie algebras and Lie algebra homomorphisms.
7. Understand irreducible representations of the Lie algebra SL(2), weights and maximal vectors, root space decomposition.
8. Familiarize with Dynkin diagrams, classification theorem.

Unit – I

Lie algebras and Lie algebra homomorphisms (definition and examples), solvable and nilpotent Lie algebra, Engel's theorem

Unit – II

Semisimple Lie algebras - Lie's theorem, Cartan's criterion, Jordan-Chevalley decomposition, Killing form, complete reducibility of representations, Weyl's theorem, irreducible representations of the Lie algebra SL(2), weights and maximal vectors, root space decomposition

Unit – III

Root systems - definition and examples, simple roots and the Weyl group, Cartan matrix of a root system, Dynkin diagrams, classification theorem.

**Books Recommended**

1. J. E. Humphreys, Introduction to Lie Algebras and Representation theory, Graduate texts in Mathematics, Springer, 1972.

**Books for Reference**

1. W. Fulton and J. Harris, Representation theory - A First Course, Graduate texts in Mathematics, Springer, 1991.
2. K. Erdmann and M. Wildon, Introduction to Lie Algebras,Springer India Pvt Ltd ,2009.
3. B.C. Hall, Lie Groups, Lie Algebras, and Representations, An Elementary Introduction, Graduate Texts in Mathematics, Springer, 2010.
4. N. Jacobson, Lie Algebras, Courier Dover Publications, 1979.

**OPE: MTH905OE**

(a) **Continuum Mechanics**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept of continuum hypothesis, stress tensor, Principal stresses, deviator and spherical stress tensors, Lagrangian and Eularian descriptions, deformation tensors, finite strain tensor, Principal strains, spherical and deviator strain components, equations of compatibility, Material derivatives, path lines and stream lines, fundamental laws of continuum mechanics, basic properties of fluid motion, Navier Stokes equation, Bemouli's equation, circulation.

**Course Learning Outcomes:** This course will enable the students to:

1. The Continuum concept and Cauchy's stress principle
2. Equations of equilibrium, Principal stresses, stress invariants
3. Lagrangian and Eularian descriptions
4. Stress ratio and finite strain interpretation
5. Differential equations of path line and stream line and mathematical solutions.
6. Derivation of Bemouli's equation and derivation of Navier stokes equation for viscous fluid.

Unit-I

Analysis of Stress: The continuum concept, homogeneity, isotropy, mass density, Cauchy's stress principle, stress tensor, equations of equilibrium, stress quadric of Cauchy, Principal stresses, stress invariants, deviator and spherical stress tensors.

Unit-II

Analysis of Strain: Lagrangian and Eularian descriptions, deformation tensors, finite strain tensor, small deformation theory, linear strain tensors and physical interpretation, stress ratio and finite strain interpretation, strain quadric of Cauchy, Principal strains, strain invariants, spherical and deviator strain components, equations of compatibility.

Unit-III

Motion: Material derivatives, path lines and stream lines, rate of deformation and vorticity with their physical interpretation, Material derivatives of volume, surface and line elements, Volume surface and line integrals, fundamental laws of continuum mechanics.

Unit-IV

Fluids: Viscous stress tensor, Barotropic flow, Stokesian fluids, Newtonian fluids, Navier Stokesequations, irrotational flow, perfect fluids, Bemouli's equation, circulation.

**Books Recommended:**

1. G.E.Mase, Continuum Mechanics ,McGraw-Hill Education, 1969
2. F. Chorlton, Textbook of Fluid Dynamics, CBS Publishers, Delhi,2004

**Books for Reference**

1. R. Chatterjee, Mathematical Theory of Continuum Mechanics ,Narosa Publishing House, New Delhi, 2015
2. G.K. Batchelor,An Introdution to Fluid Mechanics, Foundation Books, New Delhi,2005

(b) **Operation Research**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept of Linear Programming Problem, Slack and Surplus Variables-Reformulation of the General L.P.P.- Simplex Method- Matrix Notation-Duality, Markov Analysis, Markov Processes- State Transition Matrix-Transition Diagram-Brand Switching, Two-person Zero-sum games-Pay-off Matrix – some basic terms-the Maximum – Minimal Principle-Theorem on Maximum and Minimal Values of the Game Saddle Point and Value of the Game-Rule for determining a Saddle Point-Games without Saddle Points-Mixed Strategies-Graphic solution, Problem with Several Production Runs of Unequal Length etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand Mathematical Formulation of the Problem- Graphical Solution Method-Some Exceptional Cases-General Linear Programming Problem.
2. Apply Algorithm of the Simplex Method.
3. Familiarize with Regular Stochastic Matrices- Fixed Points of Square Matrices.
4. Understand Dominance Property, General rule for Dominance, Modified Dominance Property.
5. Familiarize with Characteristics- Deterministic Inventory Problems with Shortages.

Unit-I

Linear Programming Problem: Introduction: Nature and Features of Operations Research (O.R)- Convex set-Polyhedral Convex . Set-Linear Programming (L.P)-Mathematical Formulation of the Problem- Graphical SolutionMethod-Some Exceptional Cases-General Linear Programming Problem (General L.P.P) – Slack and Surplus Variables-Reformulation of the General L.P.P.- Simplex Method- Matrix Notation- Duality (Statement only of Property without Proof)- Initial Simplex Tableau- Pivot-Calculating the new Simplex Tableau Terminal Simplex Tableau- Algorithm of the Simplex Method.

Unit-II

Markov Analysis: Introduction: Probability Vectors-Stochastic Matrices – Regular Stochastic Matrices- Fixed Points of Square Matrices- Relationships between Fixed Points and Regular Stochastic Matrices- Markov Processes- State Transition Matrix-Transition Diagram-Brand Switching Analysis- Construction of State Transition Matrices—n-step Transition Probabilities- Stationary Distribution of Regular Markov Changes- Steady State (Equilibrium) Conditions- Markov Analysis
Algorithm.

Unit-III

Games and Strategies: Introduction: Two- person Zero-sum games-Pay-off Matrix – some basic terms-the Maximum – Minimal Principle-Theorem on Maximum and Minimal Values of the GameSaddle Point and Value of the Game-Rule for determining a Saddle Point-Games without Saddle Points-Mixed Strategies-Graphic solution of 2 x n and m x 2 games- Dominance Property- General rule for Dominance-Modified Dominance Property.

Unit-IV

Inventory Control: Introduction: The Inventory Decisions- Costs Associated with Inventories-Factors affecting Inventory Control- Economic Order Quantity (EOQ) – Deterministic Inventory Problems with no Shortages- Case 1: The fundamental EOQ problem; Characteristics and Corollary. Case 2: EOQ Problem with Several Production Runs of Unequal Length. Case 3: EOQ Problem with Finite

Replenishment (Production); Characteristics- Deterministic Inventory Problems with Shortages

Case 1: EOQ Problem with Instantaneous Production and Variable Order Cycle Time; Characteristics. Case 2: EOQ Problem with Instantaneous Production of Fixed Order Cycle. Case 3: EOQ Problem with Finite Replenishment (Production); Characteristics.

**Books Recommended**

1. K. Swarup, P.K. Gupta and M.Mohan, Operations Research( Ninth Edition) , Sultan Chand & Sons,
New Delhi, 2002

**Books for Reference**

1. F.S.Hillier and G.J.Lieberman,Operations Research(Second Edition),Holden-Day Inc, San Fransisco, USA. 1974
2. H.A. Taha.,Operation Research – An Introduction( Sixth Edition), Prentice-Hall of India Pvt. Ltd., New Delhi, 2002

(c) **Application of Mathematics in Finance**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic concept of Financial Management, Goals of Financial Management and main decisions of financial management, Time value of Money, Meaning of return, Meaning of risk, Parity Theorem etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand Nature and Scope of Financial Management, Difference beween risk, speculation and gambling.
2. Familiarize with Time value of Money.
3. Apply Numerical Methods like Newton Raphson Method to calculate IRR.

4. Understand Sharpe's Single index Model.
5. Calculate of Duration and Convexity of bonds

Unit-I

Financial Management - An overview; Nature and Scope of Financial Management; Goals of Financial Management and main decisions of financial management; Difference between risk, speculation and gambling.

Unit-II

Time value of Money - Interest rate and discount rate; Present value and future valuediscrete case as well as continuous compounding case; Annuities and its kinds.

Unit-III

Meaning of return; Return as Internal Rate of Return (IRR); Numerical Methods like Newton Raphson Method to calculate IRR; Measurement of returns under uncertainty situations.

Unit-IV

Meaning of risk; Difference between risk and uncertainty; Types of risk; Measurements of risk.
Calculation of security and Portfolio Risk and Return-Markowitz Model; Sharpe's Single index Model; Systematic Risk and Unsystematic Risk.

Unit-V

Taylor series and Bond Valuation; Calculation of Duration and Convexity of bonds.
Financial Derivatives — Futures, Forward, Swaps and Options; Call and Put Option; Call and Put Parity Theorem; Pricing of contingent claims through Arbitrage and Arbitrage Theorem.

**Books Recommended**

1. A. Damodaran, Corporate Finance - Theory and Practice, Wiley ,2007
2. J.C. Hull and S.Basu , Options, Futures, and Other Derivatives, Pearson, 2016
3. S.M. Ross, An Introduction to Mathematical Finance, Cambridge University Press,2011
4. M. S. Dorfman, Introduction to Risk Management and Insurance, **:** Prentice Hall India, 2009.
5. C.D. Daykin, T Pentikainen and M. Pesonen, Practical Risk Theory tor Actuaries, Chapman & Hall,1993

(d) **Optimization Technique**

**Total Marks:** (Theory: 70, Internal Assessment: 30)

**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of optimization techniques under both linear and non-linear environments. Linear optimization includes simplex method, revised simplex method, duality, sensitivity analysis, transportation and assignment problems. Non-linear optimzation includes Lagrange multipliers, Karush-Kuhn-Tucker theory. Numerical optimization techniques: line search methods, gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods, projected gradient methods, penalty methods.

**Course Learning Outcomes:** This course will enable the students to:

1. Formulate linear programming problems and solve them by using techniques, namely simplex method, revised simplex method, duality, sensitivity analysis, transportation and assignment problems.
2. Basic of multivariable calculas and non-linear optimization.
3. Learn and apply line search techniques, namely Golden Section method and Fobonacci Search methods.
4. Optimization search techniques without constraints by the methods, namely gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods, projected gradient methods, penalty methods.
5. Non-linear optimization techniques with constraints by Lagrange multipliers and Karush-Kuhn-Tucker methods.

Unit-I

Mathematical foundations and basic definitions: concepts from linear algebra, geometry, and multivariable calculus. Linear optimization: formulation and geometrical ideas of linear programming problems, simplex method, revised simplex method, duality, sensitivity analysis, transportation and assignment problems.

Unit-II

Nonlinear optimization: basic theory, method of Lagrange multipliers, Karush-Kuhn-Tucker theory. Numerical optimization techniques: line search methods, gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods, projected gradient methods, penalty methods.

## Books Recommended

1. N. S. Kambo, Mathematical Programming Techniques, East West Press, 1997.
2. E.K.P. Chong and S.H. Zak, An Introduction to Optimization, 2nd Ed., Wiley, 2010.

## Books for Reference

1. R. Fletcher, Practical Methods of Optimization, 2nd Ed., John Wiley, 2009.
2. D. G. Luenberger and Y. Ye, Linear and Nonlinear Programming, 3rd Ed., Springer India, 2010.
3. M. S. Bazarra, J.J. Jarvis, and H.D. Sherali, Linear Programming and Network Flows,.Wiley India, 2008
4. U. Faigle, W. Kern, and G. Still, Algorithmic Principles of Mathematical Programming, Kluwe, 2002.
5. D.P. Bertsekas, Nonlinear Programming, 2nd Ed., Athena Scientific, 1999.

**6.** M. S. Bazarra, H.D. Sherali, and C. M. Shetty, Nonlinear Programming: Theory and Algorithms(2nd Edn.),Wiley India, 2004

### (e) Mathematical Modelling

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The objective of this course is to study Mathematical Modelling, Autonomous System, Nonautonomous System, Syvester criterion, Liapunov's Theorems, Two-dimensional nonlinear system and linearization etc.

**Course Learning Outcomes:** This course will enable the students to

1. Familiarize with Mathematical Modelling, Classification and its characteristics.
2. Understand Autonomous System, Nonautonomous System, Sylvester criterion.
3. Check stability by Liapunov's Direct Method.
4. Familiarize with construction of Liapunov function for linear system with constant coefficients.
5. Understand test for stability based on first approximations.
6. Familiarize with Stability, Perturbation Theorems, Poincare's Linearization Theorem, Bifurcation and Chaos

Unit-I

Background of Mathematical Modelling, need and Techniques. Classification and its characteristics.

Unit-II

Autonomous System, Nonautonomous System, Sylvester criterion.

Unit-III

Liapunov's Theorems, Stability by Liapunov's Direct Method. Krasovskii's method.

Unit-IV

Construction of Liapunov function for linear system with constant coefficients.

Unit-V

Test for stability based on first approximations, Two-dimensional nonlinear system and linearization technique.

Unit-VI

Limit sets and Limit cycles, Extent of Asymptotic Stability, Lienard Equation.

Unit-VII

Stability, Perturbation Theorems, Poincare's Linearization Theorem, Bifurcation and Chaos.

**Books Recommended**

1. P. Glendinning,Stability, Instability and Chaos ,Cambridge University Press, 1994

2. T. Yoshizawa, The Stability Theory by Liapunov's Second Method ,Mathematical Society of Japan, Tokyo, 1966

**Books for Reference**

1. W. Hahn, Stability of Motion ,Springer Verlag, Berlin, 1967

2. J. L.Salle and S.Lefschetz, Stability by Liapunov's Direct Mehtod ,Academic Press, New York, 1961)

**SEMESTER -4**

**MTH100C: Discrete Mathematics**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The objective of this course is to study Sets and classes, Relations and functions, Posets, Chains and well ordered sets, Well-formed formulas, Normal forms, Primitive roots, the theory of indices, Quadratic reciprocity law, Simple continued fractions, finite and infinite continued fractions, uniqueness, representation of rational and irrational numbers as simple continued fractions etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand Equivalence relations and equivalence classes, Principle of mathematics induction etc.
2. Familiarize with Truth of algebraic systems, Calculus of predicates.
3. Apply the theory of indices.
4. Familiarize Quadratic reciprocity law, Euler's criterion, the Legendre symbol and its properties.
5. Understand representation of rational and irrational numbers as simple continued fractions.

UNIT-I

Sets and classes, Relations and functions, Equivalence relations and equivalence classes, Principle of mathematics induction, Recursive definitions, Posets, Chains and well ordered sets, Axiom of choice, Cardinal and ordinal numbers, Cantor's lemma, Set theoretic paradoxes.

UNIT-II

Propositional Calculus: Well-formed formulas, Tautologies, Equivalence, Normal forms, Truth of algebraic systems, Calculus of predicates.

UNIT-III

Primitive roots, Indices, the order of an integer modulo n, primitives roots for primes, composite number having primitive roots, the theory of indices

UNIT IV

Quadratic reciprocity law, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruence with composite modulii

Unit V

Fibonacci numbers, Fibonacci sequence, Identities involving Fibonacci number

Unit VI

Simple continued fractions, finite and infinite continued fractions, uniqueness, representation of rational and irrational numbers as simple continued fractions, rational approximation to irrational numbers, Hurwitz theorem, basic facts of periodic continued fractions and their illustrations (without proofs); Pell's equation

**Books Recommended**

1. I. Niven and H. S. Zuckerman, An Introduction to the Theory of Numbers (3rd edition) , Wiley Eastern Ltd., New Delhi, 1993
2. D. M. Burton, Elementary Number Theory (4th edition) , Universal Book Stall, New Delhi, 2002.
3. J.P. Tremblay and R.P. Manohar, Discrete Mathematics with Applications to Computer Science, McGraw Hill , 1989.
4. P. R. Halmos, Naive Set Theory, Springer India, 2009

**Books for Reference**

1. K.C.Chowdhury, A First Course In Theory Of Numbers; Asian Books Private Ltd., 2004.

**SPECIAL 2: MTH1002SP**

**(a) Number Theory and Cryptography**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** Cryptography refers the study of secure communications in presence of adversaries.The main objective of this course is to study some topics of classical number theory such as congruence, solutions of linear and quadratic congruence equations, Chinese remainder theorem; Various Primality testing and factorization algorithms; structure of finite fields and their properties; basic ideas of private and public key cryptosystems, RSA cryptosystems; digital signature schemes; the group structure of an elliptic curve and Elliptic curve cryptography(ECC) and its applications in cryptography and factorization, and some known attacks.

**Course Learning Outcome (LO):** On successful completion of the course students are expected to

**LO1:** Acquire knowledge of congruence, solutions of linear and quadratic congruence equations, and solving system of linear equations by Chinese Remainder Theorem.

**LO2:** Acquire knowledge of various Primality tests and algorithms, Polard's Rho method of factorization.

**LO3:** Acquire knowledge about finite fields, characteristic of fields and the structure of finite fields.

**LO4:** Acquire knowledge about various private and public key cryptographic systems such as RSA cryptosystems, Knapsack cryptosystem, Elliptic Curve Cryptography (ECC), key-exchange systems, digital signatures and known attacks of different cryptosystems.

**Module–1:** Congruence, Linear Diophantine Equations, Chinese Remainder Theorem, Primitive Roots, Quadratic reciprocity, Legendre and Jacobi symbol.

**Module–2:** Arithmetic functions Primality Testing and factorization algorithms, Pseudo-primes, Fermat's pseudo-primes, Pollard's rho method for factorization, Continued fractions, and Continued fraction method

**Module–3:** Fields, Finite fields, Characteristics of fields, Generators of fields, Characterisations of finite fields.

**Module–4:** Public Key cryptography, Diffie-Hellmann key exchange, discrete logarithm-based crypto-systems, RSA crypto-system, Signature Schemes, Digital signature standard, RSA Signature schemes, Knapsack problem. Introduction to elliptic curves, Group structure, Rational points on elliptic curves, Elliptic Curve Cryptography. Applications in cryptography and factorization, some of known attacks.

Unit –I

Congruence, Linear Diophantine Equations, Chinese Remainder Theorem, Primitive Roots, Quadratic reciprocity, Legendre and Jacobi symbol.

Unit – II

Arithmetic functions Primality Testing and factorization algorithms, Pseudo-primes, Fermat's pseudo-primes, Pollard's rho method for factorization, Continued fractions, Continued fraction method

Unit –III

Fields, Finite fields, Characteristics of fields, Generators of fields, Characterisations of finite fields.

Unit –IV

Public Key cryptography, Diffie-Hellmann key exchange, Discrete logarithm-based crypto-systems, RSA crypto-system, Signature Schemes, Digital signature standard, RSA Signature schemes, Knapsack problem. Introduction to elliptic curves, Group structure, Rational points on elliptic curves, Elliptic Curve Cryptography. Applications in cryptography and factorization, Known attacks.

**Books Recommended**

1. N. Koblitz, A Course in Number Theory and Cryptography, Springer, 2006.
2. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, Wiley, 2006.
3. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.

**Books for Reference**

1. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.
2. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-

Verlag, 2004.

3. J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.

4. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.

**5.** R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.

**(b) Fluid Dynamics**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:**

This course is design to introduce the basic concepttheory of stress and rate of strain, Stokes's law of viscosity, fluid motion of viscous fluid, energy dissipation, equation of motion of viscous fluid, Exact solution of Navier Stokes equation for limiting cases, Laminar boundary layer theory, Similarity solution and Blasius solution for flow about a flat plate, Energy integral equation, Blasius solution for flow past a cylindrical surface, phenomenon of separation.

**Course Learning Outcomes:** This course will enable the students to:

1. Theory of stress and rate of strain, Relation between stress and rates of strain components.
2. Derivation of Navier-Stokes equation of motion.
3. Solution of Navier Stokes equation for special cases.
4. Boundary layer thickness and derivation of boundary layer equation.
5. Similarity solution and Blasius solution for flow about a flat plate.
6. Blasius solution for flow past a cylindrical surface.

Unit -I

Theory of stress and rate of strain: Newton's law of viscosity, body and surface forces, Stress vector and components of stress tensor, state of a stress tensor. Transformation of stress components. Plane stress, principle stress and principle directions, Relation between stress and rates of strain components. Stokes's law of viscosity. Translation, rotation and rate of deformation.

Unit -II

Viscous fluid motion: Navier-Stokes equation of motion, rate of change of vorticity and circulation, rate of dissipation of energy, diffusion of a viscous filament.

Unit -III

Exact solution of Navier-Stokes equation: Flow between plates, Flow through a pipe (circular, elliptic), Suddenly accelerated plane wall, Flow near an Oscillating flat plate, Circular motion through cylinders.

Unit -IV

Laminar boundary layer theory: General outline of Boundary layer flow, Boundary layer thickness, Displacement thickness, Energy thickness, Flow along a flat plate at zero incidence, Similarity solution and Blasius solution for flow about a flat plate.

Karman's momentum integral equation, Energy integral equation, Pohlhausen solution of momentum integral equation. Two-dimensional Boundary layer equations for flow over a curved surface, Blasius solution for flow past a cylindrical surface, phenomenon of separation.

**Books Recommended**

1. Horace Lamb, Hydrodynamics , Dover Publications, 1945

2. L.M.Milne-Thomson: Theoretical Hydrodynamics(5th ed. edition), Dover Publications, 2013

3. H. Schlichting (translated by J. Kertin), Boundary Layer Theory: ,McGraw Hill, New York,2014

**Books for Reference**

1. S. Goldstein,  Modern Development of Fluid Dynamics, Vol –I ,Dover Publication, New York,1938

2. G.K. Batchelor,An Introduction to Fluid Dynamics , Cambridge University Press, 2012

**(c) Finite Element Method**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:**

This course is design to introduce the basic concepttheory of discretization, subdivision, continuity, convergence, bounds, error, Finite Element Methods, local and global coordinates, interpolation functions, formulation by Galerkin method, Two and Three-dimensonal formulationsetc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand the basic concepttheory of discretization, subdivision, continuity.
2. Apply Finite Element Methods.

3. Apply Galerkin method.
4. Familiarize with triangular and quadrilateral elements, three-dimensional formulation, tetrahedron element, brick element.

Unit-I

Introduction: Basic concepts of process of discretization, subdivision, continuity, convergence, bounds, error.

Unit-II

Finite Element Methods: Introduction, general idea of element configuration, approximation models or functions. Energy methods, methods of weighted residuals. Introduction to variational calculus.

Unit-III

One-dimensional Stress Deformation: Element configuration, local and global coordinates, interpolation functions, stress-strain relationship, element equations and assembling, direct stiffness method, formulation by Galerkin method.

Unit-IV

One-dimensional flow: Theory and formulation, finite element formulation, variational approach, Galerkin method, boundary conditions.

Unit-V

Two and Three-dimensonal formulations: Introduction, two-dimensional formulation, triangular and quadrilateral elements, three-dimensional formulation, tetrahedron element, brick element.

**Books Recommended**

1. C. S Desai and T. Kundu, Introductory Finite element method ,CRC Press, 2001

2. D. Braess and L. L. Schumaker, Finite elements: theory, fast solvers and applications in solid mechanics ,Cambridge University Press, 2001

3. S. C. Brenner and L. R. Scott, The mathematical theory of finite element methods, Springer, 2008

**Books for Reference**

1. P. G. Ciarlet,The finite element method for elliptic problems ,North Holland, 1978
2. V. Thomee, Galerkin finite element methods for parabolic problems ,Springer, 1997

**(d) Algebraic Number Theory**

**Total Marks: 100** (Theory: 70, Internal Assessment: 30)

**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5 (4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** Algebraic number theory is a branch of mathematics where we use the techniques of abstract algebra to study integers, rational numbers, and their generalizations.The main objective of this course is to study basic concepts of Algebraic numbers; number fields in particular, quadratic fields, cyclotomic polynomials and fields; Numerical invariants of number fields such as Discriminants; Field Norm and Field Traces;Algebraic Integers; Integral Bases; Problems for quadratic and cubic cases; Units in Number Rings, Dirichlet's Unit Theorem; Ideal Theory: norms of ideals, fractional ideals, Ideal Classes-The Class Group; Class Numbers of Quadratic Fields and Cyclotomic fields.

**Course Learning Outcome:** On successful completion of the course students are expected to

**1:** Acquire knowledge of algebraic numbers, number fields and its invariants, Field norms and Field traces .

**2:** Acquire knowledge of algebraic integers, rings of integers and problems for quadratic and cubic cases.

**3:** Acquire knowledge of class number of Quadratic field and Cyclotomic fields.

**4:** Acquire knowledge of number rings and Dirichlet's Unit Theorem.

**5:** Acquire knowledge of ideal theory in particular norms of ideals and fractional ideals.

**6:** Acquire knowledge of Class Group, Class Numbers of Quadratic Fields and Cyclotomic Fields.

Unit-I

Algebraic numbers, number fields, Discriminants, Norms and Traces.

Unit-II

Algebraic Integers, rings of integers, Integral Bases, Problems for quadratic and cubic cases.

Unit-III

Arithmetic of Number Fields: Quadratic Fields, Cyclotomic polynomials and fields.

Unit-IV

Units in Number Rings, Dirichlet's Unit Theorem.

Unit-V

Ideal Theory: norms of ideals, fractional ideals.

Unit-VI

Ideal Classes-The Class Group, Class Numbers of Quadratic Fields and Cyclotomic fields.

**Books Recommended**

1.R. A. Mollin, *Algebraic Number Theory* ,CRC Press, 1999

2. I. N. Stewart & D. Tall, *Algebraic Number Theory and Fermat's Last Theorem(*3rd ed),AK Peters Ltd, 2008

**Books for Reference**

1. J. Esmonde & M. Ram Murty, *Problems in Algebraic Number Theory*, GTM Vol. 190,Springer-Verlag, 2006

### (e)Fuzzy Sets and Applications

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5(4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of fuzzy theory and applications.

**Course Learning Outcomes:** This course will enable the students to:

1. Differentiate fuzzy sets from crisp sets.
2. Understand the extension principale of fuzzy sets.
3. Differentiate crisp relation to fuzzy relation.
4. Understand fuzzy numbers and their arithmetic.
5. Undertand fuzzy logic and its applications in approximate reasoning.
6. Understand fuzzy controller.
7. Apply fuzzy theory to decision-making problems.

Unit -I

Fuzzy sets: Basic definitions, d-level sets, convex fuzzy sets, basic operations on fuzzy sets, types of fuzzy sets, Cartesian products, algebraic products, bounded sum and difference.

Extension principle: The Zadeh extension principle, image and inverse image of fuzzy sets, fuzzy numbers, elements of fuzzy arithmetic.

Unit -II

Fuzzy relations and fuzzy graphs: Fuzzy relations and fuzzy sets, composition of fuzzy relations, min-max composition and its properties, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy relations equations, fuzzy graphs, similarity relation.

Unit -III

Fuzzy logic: An overview of classical logic, multivalued logic, fuzzy propositions, fuzzy quantifiers, linguistic variable and hedges, inference from conditional fuzzy propositions, the compositional rule of inference.

Approximate reasoning: An overview of fuzzy expert system, fuzzy implications and their selection, multiconditional approximate reasoning.

Unit -IV

Introduction to fuzzy control Fuzzy controllers, fuzzy rule base, fuzzy inference engine, fuzzification,defuzzification and the various defuzzification methods (the centre of area, the centre of maxima and the mean of maxima methods).

Unit -V

Decision making in fuzzy environment: Individual decision making, mult-person decision making, multicriteria decision making, multi stage decision making, fuzzy ranking methods, fuzzy linear programming.

**Books Recommended**

1. G.J. Klir and B.Yuan: Fuzzy Sets and Fuzzy Logic- Theory and Applications, Prentice Hall of India, 1995.

2. H.J. Zimmermann: Fuzzy Theory and its Application, Allied Publishers Ltd., 1991

**Books for Reference**

1.G. Bojadziev, M. Bojadziev, Fuzzy Sets, Fuzzy Logic, Applications, World Scientific,1995

**(f) Dynamical Systems**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5(4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of dynamical systems and vector fields, fixed point, equilibrium point, periodic point, stability of a fixed point, equilibrium point, concept of limit cycle and torus, topological study of nonlinear differential equations, randomness of orbits of a dynamical system, Chaos, Fractal geometry, construction of the middle third Cantor set, Von Koch curve, Sierpinski gasket, self similar fractals with different similarity ratio, Julia set, measure and mass distribution, Housdorff measure, Housdorff dimension and its properties, upper estimate of box dimension, generalized Cantor set and its dimension etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand dynamical systems and vector fields, the fundamental theorem.
2. Familiarize with Feigenbaum's universal constant, nonlinear oscillators.
3. Understand Hamiltonian system, various types of Oscillators in nonlinear system.
4. Solve of nonlinear differential equations.
5. Familiarize with Housdorff measure, Housdorff dimension and its properties.
6. Understand measurement of asset at scale box dimension, its equivalent versions, properties of box dimension.

Unit-I

Dynamical systems and Vector fields, the fundamental theorem, existence and Uniqueness, continuity of solution in initial condition, orbit of a map, fixed point, equilibrium point, periodic point, circular map, configuration space and phase space.

Unit-II

Stability of a fixed point, equilibrium point, concept of limit cycle and torus, hyperbolicity. Quadratic Map, Period doubling phenomenon, Feigenbaum's universal constant.

Unit-III

Nonlinear oscillators – conservative system. Hamiltonian system. Various types of Oscillators in nonlinear system. Solutions of nonlinear differential equations.

Unit-IV

Phenomenon of losing stability, Quasiperiodic motion. Topological study of nonlinear differential equations. Poincare map.

Unit-V

Randomness of orbits of a dynamical system. Chaos. Strange attractors. Various routes to chaos. Onset mechanism of turbulence.

Unit –VI

Basic idea of Fractal geometry, construction of the middle third Cantor set, Von Koch curve, Sierpinski gasket, self similar fractals with different similarity ratio, Julia set, measure and mass distribution, Housdorff measure, Housdorff dimension and its properties.

Unit – VII

Measurement of asset at scale box dimension, its equivalent versions, properties of box dimension, box dimension of middle third Cantor set and other simple sets, upper estimate of box dimension, generalized Cantor set and its dimension.

**Books Recommended**

1. R. L. Devany: An Introduction to Chaotic Dynamical Systems, Addison-Wesley Publishing Co. Inc, 1989.
2. M. W. Hirsch, S. Smale: Differential Equation, Dynamical System and an introduction to chaos, Academic Press,2012
3. K. Falconer, Fractal Geometry: Mathematical Foundations and applications, Wiley-Blackwell, 2014

**Reference books:**

1. V.I. Arnold, Dynamical systems, Bifurcation Theory and Catastrophy Theory, Springler Verlag, 1992.

2. D.K. Arrowsmith & C.M. Place, Introduction to Dynamical Systems, Cambridge University Press,1990

3. K.J. Falconer, The Geometry of Fractals Sets, Cambridge University Press, 1985.

4. M.F. Barnsley,Fractals everywhere, Academic Press., 1988.

**(g) Commutative Algebra**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 5(4+1+0)
**Duration:** 14 Weeks (84 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the concept ofextension and contraction of ideals, prime spectrum and Jacobson radical of a ring, rings of formal power series, localisation, extended & contracted ideals in rings of fractions, primary decomposition, Noetherian rings, Artin rings, integral dependence, integrally closed domains, valuation rings, discrete valuation rings, dedekind domains, fractional ideals.

**Course Learning Outcomes:** This course will enable the students to:

1. Learn the concept ofprime spectrum of rings
2. Apply the Jacobson radical of a ring
3. Learn and apply the prime avoidance lemma
4. Learn localisation and its properties.
5. Learn Noetherian and Artin rings and their significances
6. Learn and apply the going up and going down theorem
7. Learn the significances of discrete valuation rings, dedekind domains, fractional ideals

Unit – I

Extension and Contraction of ideals, Prime spectrum of Rings, Jacobson radical of a ring, Prime avoidance lemma, Rings of formal power series, Restriction and extension of scalars.

Unit –II

Localisation, Local properties, Extended & contracted ideals in rings of fractions, Primary decomposition, First and second uniqueness theorem of primary decomposition, Noetherian rings, Primary decomposition in Noetherian rings, Artin rings, Structure theorem for Artin rings.

Unit – III

Integral dependence, Going up theorem, Going down theorem, Integrally closed domains, Valuation rings, Hilbert's Nullstellensatz theorem, Discrete valuation rings, Dedekind domains, Fractional ideals.

**Books Recommended**

1. M.F. Athiyah & I.G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 1969.

**Books for Reference**

1. B. Singh, Basic Commutative Algebra, World Scientific Publishing Co., 2011.
2. D. Eisenbud, Commutative Algebra with a view towards algebraic geometry, Springer Verlag, 1995.
3. O. Zariski & P. Samuel, Commutative Algebra, Vol. 1 & 2, SpringerVerlag, 1975.
4. R.Y. Sharp, Steps in Commutative Algebra, Cambridge University Press, 1990

**OPE 2: MTH1003OE**

(a) **Combinatorics**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4 (3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the concept ofcounting principles, set partitions, different kinds of Striling numbers, number partitions, lattice paths, Gaussian coefficients, Aztec diamonds, formal series, probability generating functions, generating functions, hypergeometric sums, hypergeometric series, Sieve methods, Mobius inversion, enumeration and patterns, polyominoes.

**Course Learning Outcomes:** This course will enable the students to:

1. Apply the counting principles
2. Apply the binomial and multinomial theorem
3. Learn and apply the concept of multisets
4. Learn and apply the different types of lattice paths
5. Learn and apply the concepts of set partions, number partitions and permutations.
6. Learn and apply the formal series and infinite matrices
7. Learn the significances of generating functions and exponential generating functions
8. Apply the recurrence operators in hypergeometric sums and its related algrithms
9. Apply the different versions of principle of inclusion-exclusion
10. Learn symmetries and patterns and their applications.
11. Learn Polya-Redfield theorem and its applications.

Unit- I

Counting principles, multinomial theorem, set partitions and Striling numbers of the second kind, permutations and Stirling numbers of the first kind, number partitions, Lattice paths, Gaussian coefficients, Aztec diamonds.

Unit - II

Formal series, infinite sums and products, infinite matrices, inversion of sequences, probability generating functions.

Unit - III

Generating functions, evaluating sums, the exponential formula, more on number partitions and infinite products, Ramanujan's formula.

Unit - IV

Hypergeometric sums, summation by elimination, infinite sums and closed forms, recurrence for hypergeometric sums, hypergeometric series.

Unit - V

Sieve methods, inclusion-exclusion, Mobius inversion, involution principle, Gessel-Viennot lemma, Tutte matrixtree theorem

Unit - VI

Enumeration and patterns, Polya-Redfield theorem, cycle index, symmetries on N and R, polyominoes

**Books Recommended**

1. M. Aigner. A Course in Enumeration. Springer,2012.

**Books for Reference**

1. C. Berge. Principles of Combinatorics. Academic Press, 1971.
2. J. Riordan. Introduction to Combinatorial Analysis. Dover, 2002.
3. M. Bona. Introduction to Enumerative Combinatorics. Tata McGraw Hill, 2007.

(b) **Differential Geometry**

**Total Marks:** (Theory: 70, Internal Assessment: 30)

**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4(3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic ofSpace curves, plane curves, curvature, torsion and Serret-Frenet formula, osculating planes, osculating circles and spheres, theory of surfaces, geodesics, tensors, Laplacian operators in tensor form, physical components etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand theory of space curves.
2. Familiarize with parametric curves on surfaces, direction coefficients, first and second fundamental forms, principal and Gaussian curvatures etc.
3. Understand Canonical geodesic equations, nature of geodesics on a surface of revolution, Clairaut's theorem, normal property of geodesics, torsion of a geodesic etc.
4. Familiarize with coordinate transformation and Jacobian, contra-variant and covariant vectors.
5. Understandcovariant and intrinsic derivatives, curvature tensor and its properties.

Unit-I

Theory of space curves: Space curves, plane curves, curvature, torsion and Serret-Frenet formulae. Osculating planes, osculating circles and spheres. Existence of space curves. Evolutes and involutes of curves.

Unit-II

Theory of surfaces: Parametric curves on surfaces. Direction coefficients. First and second fundamental forms. Principal and Gaussian curvatures. Lines of curvature, Euler's theorem. Rodrigue's formula, conjugate and asymptotic lines.
Developables: Developable associated with space curves and curves on surfaces, minimal surfaces.

Unit-III

Geodesics: Canonical geodesic equations. Nature of geodesics on a surface of revolution. Clairaut's theorem. Normal property of geodesics. Torsion of a geodesic. Geodesic curvature. Gauss-Bonnet theorem. Surfaces of constant curvature. Conformal mapping. Geodesicmapping. Tissot's theorem.

Unit-IV

Tensors: Summation convention and indicial notation, coordinate transformation and Jacobian, contra-variant and covariant vectors, tensors of different types, algebra of tensors and contraction, metric tensor and 3-index Christoffel symbols

Unit-V

Parallelism of vectors, angle between two vectors, covariant and intrinsic derivatives, curvature tensor and its properties, curl, divergence and Laplacian operators in tensor form, physical components.

**Books Recommended:**

1. T.J.Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.

**Books for Reference:**

1. B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
2. C.E.Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press 2003.
3. D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
4. S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
5. B. Spain, Tensor Calculus: A Concise Course, Dover Publications, 2003.

**(c) Scientific Computing**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4(3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of iterative methods for nonlinear equations, numerical integration based on interpolation, initial value problems for ordinary differential equations, finite difference schemes for partial differential equations, Finite difference schemes for initial and boundary value problems.

**Course Learning Outcomes:** This course will enable the students to:

1. Apply quadrature methods, Gaussian quadrature methods.
2. Apply Euler method, Runge- Kutta methods, multi-step methods, predictor-corrector method to solve initial value problems for ordinary differential equations.
3. Solve boundary value problems by FTCS, Backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff method, upwind scheme.

Unit-I

Errors; Iterative methods for nonlinear equations; Polynomial interpolation, spline interpolations; Numerical integration based on interpolation, quadrature methods, Gaussian quadrature.

Unit-II

Initial value problems for ordinary differential equations - Euler method, Runge- Kutta methods, multi-step methods, predictor-corrector method, stability and convergence analysis.

Unit-III

Finite difference schemes for partial differential equations - Explicit and implicit schemes; Consistency, stability and convergence; Stability analysis (matrix method and von Neumann method), Lax equivalence theorem.

Unit-IV

Finite difference schemes for initial and boundary value problems (FTCS, Backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff method, upwind scheme).

**Books Recommended**

1. D. Kincaid and W. Cheney, Numerical Analysis: Mathematics of Scientific Computing(3rd Ed.), AMS, 2002.

2. G. D. Smith, Numerical Solutions of Partial Differential Equations( 3rd Ed.), Calrendorn Press, 1985.

**Books for Reference**

1. K. E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989.

2. S. D. Conte and C. de Boor, Elementary Numerical Analysis - An Algorithmic Approach, McGraw-Hill, 1981.

3. R. Mitchell and S. D. F. Griffiths, The Finite Difference Methods in Partial Differential Equations, Wiley, 1980.

## (d) **Industrial Mathematics**

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4(3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of financial derivatives, ca pital market theory, static and continuous- time model, a single period option pricing model, multi period option pricing model, Cox-Ross-Rubistein model, the Ito's Lemma and the Ito's integral etc.

**Course Learning Outcomes:** This course will enable the students to:

1. Understand financial derivatives, types of financial derivatives etc.
2. Familiarize with Capital Market Theory, Static and Continuous- Time model.

3. Understand multi period option pricing model, Cox-Ross-Rubistein model.

Familiarize with Ito's Lemma and the Ito's integral.

Unit -I

An introduction to Financial Derivatives, types of financial derivatives – Forward and Futures; Options and its kinds and SWAPS.

Unit -II

The arbitrage theorem and introduction to Portfolio Selection and Capital Market Theory, Static and Continuous-Time model.

Unit -III

A single period option pricing model, multi period option pricing model, Cox-Ross-Rubistein model, bounds on option price.

Unit -IV

The Ito's Lemma and the Ito's integral.

**Books Recommended**

1. J. C. Hull and S. Basu , Options, Futures, and Other Derivatives, Pearson, 2016

**Books for Reference**

1. S. M. Ross, An Introduction to Mathematical Finance, Cambridge University Press, 2011
2. S. N. Neftci, An Introduction to the Mathematics of Financial Derivatives, Academic Press,1996

## (e) Biomechanics

**Total Marks:** (Theory: 70, Internal Assessment: 30)
**Workload:** 4 Lectures, 1 Tutorial (per week) **Credits:** 4(3+1+0)
**Duration:** 14 Weeks (70 Hrs.) **Examination:** 3 Hrs

**Course Objectives:** The primary objective of this course is to introduce the basic of Newton's equations of motion, mathematical modelling, continuum approach, segmental movement and vibrations, fluid dynamic forces acting on Moving Bodies, Flyig and Swimming, Blood Flow in Heart, Lung, Arteries, and Veins etc.

**Course Learning Outcomes:** This course will enable the students to:

Familiarize with Newton's equations of

1. Familiarize withNewton's equations of motion, mathematical modelling, continuum approach etc.
2. Understand Blood Flow in Heart, Lung, Arteries, and Veins etc.

Prerequisite : Fluid Mechanics (See MM 503. MM 504, MM 5'05-8)

Newton's equations of motion. Mathematical modeling. Continuum approach.

Segmental Movement and Vibrations.

External Flow: Fluid Dynamic Forces Acting on Moving Bodies.

Flying and Swimming.

Blood Flow in Heart, Lung, Arteries, and Veins.

Micro-and Macrocirculation.

**Books Recommended**

1. Y.C. Fung, Biomechanics, Springer-Verlag, New York lnc., 1990.