Savitribai Phule Pune University

(Formerly University of Pune)

Two - Year Post - Graduate Degree Program in

MATHEMATICS

(Faculty of Science & Technology)

Syllabi for

M.A. / M. Sc. (Mathematics)

(For Department of Mathematics, Savitribai Phule Pune University, Pune-411007)

Syllabus under National Education Policy (NEP)
With effect from Academic Year 2023-24

(1) **Title of the Program**: M.A./M. Sc. (Mathematics)

(2) **Duration**: TWO years (Four semesters) Full-time Post - Graduate Degree Program

(3) **Intake Capacity**: 60 students

(4) **Total number of credits**: 88 credits (minimum)

(5) **Preamble**: The Department of Mathematics, Savitribai Phule Pune University, right from its inception in 1949, is recognized as a leading Department in teaching as well as research in Mathematics and allied areas. The Department was recognized as a Centre for Advanced Study (CAS-II) by the UGC (2016-21), Govt of India. Prior to CAS-II status, the Department was also recognized at the national level under various schemes, such as, DSA (UGC), COSIST(DST), FIST (DST), and NBHM. The UGC has identified three thrust areas for the Department, namely Algebra, Analysis and Discrete Mathematics for CAS. The Department offers M.A./M.Sc. (Mathematics), M.Sc. (Industrial Mathematics with Computer Applications) and Ph. D. (Mathematics) programs.

(6) **Program Objectives:** Some of the main objectives of M.A. / M.Sc. (Mathematics) Program are as follows:

   (a) To provide students with an environment that is conducive to their academic development and overall progress.
   (b) To impart students the mathematical knowledge and necessary skills so that they develop a better appreciation and understanding of modern mathematics.
   (c) To motivate students to explore various opportunities in the field of academics and industrial sector.
   (d) To develop competence among the students so that they are able to apply mathematics in various spheres of life.

(7) **Program Outcomes:** After successful completion of 2 years M.A. / M.Sc. (Mathematics) Program from the Department of Mathematics, Savitribai Phule Pune University, a student is expected to have a proficiency in understanding and confidence in implementation of the knowledge gained, along with the following program-cum-learning outcomes.

   (a) The students will have carried out their basic academic development as measured through various indicators such as grades, participation in various competitions, professional skills acquired, appreciation for research in mathematics.
   (b) The students would gain an understanding of fundamentals of mathematics and also acquire necessary skills resulting into better appreciation of modern mathematics and its significance.
   (c) The students would be able to grab various opportunities in both academics and industrial sector.
   (d) The students would be able to apply mathematics in practical situations including popularization of mathematics and dissemination of mathematical knowledge among the masses.

(8) **Program Structure of M.A./M.Sc. (Mathematics)**: For M.A./M.Sc. (Mathematics) Degree, a student has to earn the minimum 88 credits from at least FOUR semesters. The structure of the program is as follows:

   (a) In each of the four semesters I, II, III, and IV, the Department will offer at least 22 credits.
   (b) In each semester, there will be three mandatory courses each of 4 credits, and one elective course. Also, in each of the semesters I, II, and III, there will be a mandatory course of 2 credits.
   (c) In addition to (b), there will be compulsory courses as follows:

      Sem I-Research Methodology (RM) - 4 credits
      Sem II-On Job Training (OJT) - 4 credits
      Sem III - Research Project (RP1) - 4 credits
      Sem IV- Research Project (RP2)- 6 credits.

(d) Each course of 4 credits, other than OJT and RP, comprises of 2T+2P or 3T+1P (T-Theory, P-Practical).
(e) Each course of 2 credits comprises of 2T or 2P or 1T+1P.
(f) A student has to attend 1-hour classroom teaching per week for one credit of theory and 2 hours lab work/problem-solving session/ related activities per week for one credit of practical.
(g) Practical sessions (lab work/problem-solving session/related activity) will be conducted in batches. A batch for such sessions will be of size maximum of 12 students.
(h) The modus-operandi for the conduct and evaluation of a Research Project Course will be decided by the Departmental Committee from time to time as per the needs.
(i) The Department may conduct necessary lectures/workshops as a part of OJT.

(9) **Exit Option:** After successful earning of 44 credits offered by the Department for the first two semesters (First year-I, II Sem), a student will have the option of exit from the program. In this case, the student will be conferred with PG Diploma in Mathematics.

(10) **Evaluation Rules:** The general policy and rules of Savitribai Phule Pune University, and UGC are to be followed.

(a) Each course of 4 credits (T + P) will carry 100 marks and the evaluation of the course will be carried out by considering T and P jointly. There will be Continuous Assessment (CA) of 50 marks and End Term Examination (ETE) of 50 marks for each course.
(b) The CA will be based on minimum two internal tests (IT). In addition, a teacher may consider one or more of the following.
   I. Home Assignment(s)
   II. Seminar/Presentation (Individual / Group)
   III. Laboratory assignment
   IV. Group Discussions / Oral
   V. Research Paper Review
   VI. Technology Demonstration
(c) For passing a course, a student has to score a minimum of 30% marks in each of the CA and ETE <u>separately</u> and a minimum of 40% marks in the <u>combined grading</u> of CA and ETE. If a student fails to score a minimum of 30% marks in CA in a course, then the result of such a course will be FAIL.
(d) For both OJT and RP, the CA will be based on grades awarded by guide/mentor while the ETE will be based on presentation/oral/discussion/ any other criterion decided by the departmental committee. Also, for RP, the dissertation will be compulsory.
(e) If a student fails in a course (with a minimum score of 30% marks in CA), then he/she can improve the performance in CA of a "failed course" in any of the forthcoming semesters in which the course is subsequently conducted and, in this case, the student will have to appear for the ETE at the same time also for the said course.
(f) Provision of (e) can be availed within the stipulated period as per UGC/SPPU norms.
(g) The rules/directives issued by the Department/ Savitribai Phule Pune University/Govt. Maharashtra/any other competent authority from time to time will be made applicable.

(11) **ATKT Rules**: A student who wishes to take admission to the second year (register for third or fourth semester) of M. A. /M. Sc. (Mathematics) program must have earned at least 22 credits

from the total credits of two semesters of the first year of M.A./M.Sc. (Mathematics).

(12) **Research Project (RP-1 & RP-2):**

Course outcome: Research Project(s) by the student(s) portray the culmination of study toward the PG degree with a specialization in mathematics at the Department of Mathematics, Savitribai Phule Pune University. This offers an opportunity for the students to apply and demonstrate the knowledge gained from the core courses in mathematics, which ultimately would open the doors of applications and practicality of Mathematics, undertake problem(s) identification, and formulation, and devise a mechanism to find an approximate or best-fit solution for it. Also, a student is adept to take steps to bespeak his/her knowledge gained during the project period and demonstrate it as and when it is required in the professional career.

Procedures and guidelines for the conduct of the Research project:

(a) A student is supposed to register for the course RP-1 and RP-2 separately in a group of 2 to 4 students.
(b) A student will carry out the academic activity for the course throughout the semester.
(c) The course is to be completed under the supervision and guidance of a teacher. Each teacher of the Department of Mathematics, Savitribai Phule Pune University is expected to guide at least one group of students.
(d) The respective teacher is expected to engage a group of students for at least 4 hours/week for RP-1 and at least 6 hours/week for RP-2.
(e) Every group will submit a dissertation at the end of the semester duly signed by all group members and the respective teacher.

(13) **On Job Training (OJT)** In this course, the students are expected to do the On Job Training (OJT) in appropriate Industries/Government sectors/Institute etc. to get hands on experience. The department may conduct necessary lectures/workshops/seminars as a part of OJT. The course will be conducted as per the guidelines of the Department/the University and the Government of Maharashtra.

(14) **Completion of the Degree Program**:

(a) In order to qualify for the award of M.A./M.Sc. (Mathematics) Degree, a student has to earn minimum 88 credits and also need to complete the compulsory audit courses as prescribed by the University from time to time.
(b) If a student fails in a course then the said course will not be considered for calculation of SGPA/CGPA and overall grade. Only those courses in which the student has passed will be considered for calculating the SGPA/CGPA and overall grade.
(c) The applicable policies and procedures laid down by SPPU will be followed for the conduct of examinations, evaluations and declaration of the results.

(15) The Departmental Committee in its meeting with the majority may introduce/design additional course(s) and include/exclude/modify the existing course(s) to accommodate the then developments from time to time.

Savitribai Phule Pune University
FACULTY OF SCIENCE AND TECHNOLOGY
Department of Mathematics, SPPU, M.Sc. Mathematics Programme
Credit distribution structure for Two Years/One Year PG Degrees

Year	Level	Semester	Course Type	Course Code	Course Title	Credit	Credit Distribution
1	6.0	I	Core	MTS-101	Algebra	4	(3T + 1P)
			Core	MTS-102	Linear Algebra	4	(3T + 1P)
			Core	MTS-103	Topology	4	(3T + 1P)
			Core	MTS-104	Programming with Python	2	(1T + 1P)
			Elective		Choose anyone from List A	4	(2T + 2P)
			RM	MTS-RM	Research Methodology	4	(2T + 2P)
		II	Core	MTS-201	Rings and Modules	4	(3T + 1P)
			Core	MTS-202	Complex Analysis	4	(3T + 1P)
			Core	MTS-203	Measure and Integration	4	(3T + 1P)
			Core	MTS-204	Programming with C++	2	(1T + 1P)
			Elective		Choose anyone from List A	4	(2T + 2P)
			OJT/FP	MTS-OJT	On Job Training	4	(2T + 2P)

2	6.5	III	Core	MTS-301	Functional Analysis	4	(3T + 1P)
			Core	MTS-302	Advanced Calculus	4	(3T + 1P)
			Core	MTS-303	Graph Theory	4	(3T + 1P)
			Core	MTS-304	Differential Equations	2	(1T + 1P)
			Elective		Choose any one from List A	4	(2T + 2P)
			RP/ Elective	MTS-RP-1	Research Project/ Choose any one from List A	4	(2T + 2P)
		IV	Core	MTS-401	Partial Differential Equations	4	(3T + 1P)
			Core	MTS-402	Advanced Linear Algebra	4	(3T + 1P)
			Core	MTS-403	Number Theory	4	(3T + 1P)
			Elective/ RP		Choose anyone from List A / Research Project	4	(2T + 2P)
			RP	MTS-RP-2	Research Project	6	(4T+2P)

Abbreviations: OJT: On Job Training: Internship/ Apprenticeship; RM: Research Methodology; Research Project: RP; T- Theory Course, P – Practical course.

1T means 1hr of teaching per week and 1P means 2hrs of teaching/practical /tutorial/lab per week for 15 weeks. Hence (3T+1P=75 hrs) and (2T+2P=90 hrs).

Note:

1. **In any case, students must earn 10 credits for a Research project in the second year of a PG degree.**
2. **The courses which do not have practical 'P' will be treated as 'T'.**
3. **The provided syllabus and reference books are a general outline. They can be adapted and expanded based on the specific requirements of the Department and the expertise of the faculty members teaching the course.**

List A

Course Code	**Course Title**	**Credits (T + P)**	Credits Distribution
MTE-1	Numerical Analysis	4	2T + 2P
MTE-2	Combinatorics	4	2T + 2P
MTE-3	Operations Research	4	2T + 2P
MTE-4	Differential Equations and Dynamical Systems	4	2T + 2P
MTE-5	Representation Theory	4	2T + 2P
MTE-6	Computational Geometry	4	2T + 2P
MTE-7	Lattice Theory	4	2T + 2P
MTE-8	Boundary Value Problems	4	2T + 2P
MTE-9	Commutative Algebra	4	2T + 2P
MTE-10	Matroid Theory	4	2T + 2P
MTE-11	Statistics and Probability	4	2T + 2P
MTE-12	Algebraic Number Theory	4	2T + 2P
MTE-13	Integral Equations and Transforms	4	2T + 2P
MTE-14	Field Theory	4	2T + 2P
MTE-15	Coding Theory	4	2T + 2P
MTE-16	Financial Mathematics	4	2T + 2P
MTE-17	Algebraic Topology	4	2T + 2P
MTE-18	Cryptography	4	2T + 2P
MTE-19	Differential Geometry	4	2T + 2P
MTE-20	Introduction to Data Science	4	2T + 2P
MTE-21	Mechanics	4	2T + 2P
MTE-22	Advanced Calculus II	4	2T + 2P
MTE-23	Advanced Linear Algebra	4	2T + 2P
MTE-24	Banach Algebra	4	2T + 2P
MTE-25	Logic and Set Theory	4	2T + 2P
MTE-26	Quantum Computing	4	2T + 2P
MTE-27	Statistical Inference	4	2T + 2P
MTE-28	Data Mining	4	2T + 2P
MTE-29	Machine Learning	4	2T + 2P
MTE-30	Artificial Intelligence	4	2T + 2P
MTE-31	Design and Analysis of Algorithms	4	2T + 2P
MTE-32	Theory of Computer Science	4	2T + 2P
MTE-33	Computer Graphics	4	2T + 2P
MTE-34	Image Processing	4	2T + 2P
MTE-35	Topics in Discrete Mathematics-I	4	2T + 2P
MTE-36	Topics in Computational Mathematics	4	2T + 2P
MTE-37	Topics in Computer Science-I	4	2T + 2P
MTE-38	Topics in Algebra-I	4	2T + 2P
MTE-39	Topics in Analysis-I	4	2T + 2P
MTE-40	Topics in Applied Mathematics	4	2T + 2P
MTE-41	Online Courses SWAYAM/NPTEL/Any other Elective Courses approved by the Departmental Committee of the Department	4	2T + 2P

Syllabus for Core Course

MTS-101: Algebra

Course Description:

The aim of this course is to study concept of different types of groups and their properties. Student will develop an understanding of the notions such as subgroups, permutation groups and alternating groups, group isomorphism theorem and its applications, Sylow theorems and their applications.

Course Objectives:

On completion of the course, student will be able to understand

- The basics of abelian groups and non-abelian groups.
- The concept of homomorphism and isomorphism of groups and isomorphism theorems
- Group actions, Orbit Stabilizer theorem, Examples of group actions
- Conjugacy classes, class equation, Sylow theorems.
- Simple groups, Solvable groups, Nilpotent groups
- Classification of finitely generated Abelian groups.

Course Contents:

1) **Prerequisites:** Introduction to Groups, Symmetries of a square, dihedral group, rotation groups, Elementary Properties of Groups.
2) **Groups:** Homomorphisms, Subgroups and cosets, Cyclic groups, Properties of cyclic groups, Lagrange's Theorem and consequences.
3) **Normal Subgroups and Factor Groups:** Normal Subgroups, Factor Groups, Isomorphism Theorems, Automorphisms, Cayley's Theorem, Applications of Factor Groups, Simple groups, Internal Direct Products, External direct product.
4) **Group Actions:** Definition and examples, Orbit Stabilizer Theorem, Conjugacy and Class equation.
5) **Sylow Theorems and Applications:** Normal series, Composition series, Jordan Holder Theorem, Solvable groups, p-groups, Nilpotent groups.
6) **Permutation Groups:** Cycle decomposition, Structure of conjugacy in permutation groups, Alternating group, Simplicity of Alternating group.
7) **Structure Theorem of Groups:** Direct products, Fundamental Theorem of finitely generated Abelian groups, Isomorphism classes of finite Abelian Groups.

Reference Books:

- Joseph Rotman, An Introduction to the Theory of Groups, (Springer, Fourth Edition), 1995.
- Michael Artin, Algebra, (Pearson, second edition), 2010.
- Vivek Sahai & Vikas Bist, Algebra, (Alpha Science International Ltd, Second Edition), 2003.
- Dummit D. and Foote R., Abstract Algebra, 2nd Edition, Wiley Eastern Ltd.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, (Cambridge University Press, Second Edition), 1995 (Indian Edition).
- Joseph A. Gallian, Contemporary Abstract Algebra, Nineth Edition, Taylor and Francis.

MTS-102: Linear Algebra

Course Description:

Linear Algebra is an intermediate-level course that focuses on the study of vector spaces, linear transformations, inner product spaces, bilinear forms, modules, and free modules. The course explores various concepts and techniques in linear algebra and their applications in diverse fields such as mathematics, physics, computer science, and engineering.

Course Objectives:

- To provide a solid understanding of vector spaces and their properties, including subspaces, bases, and dimensions.
- To explore the theory of linear transformations and their representation using matrices.
- To introduce canonical forms such as eigenvalues and eigenvectors, diagonalizability, and Jordan forms, and understand their significance in linear algebra.
- To study inner product spaces and their properties, including orthogonality, adjoint operators, and unitary operators.
- To delve into the theory of bilinear forms, including their classification and matrix representations.
- To introduce the concept of modules and further explore their properties and applications.
- To understand free modules, linear independence, bases, and the relationship between matrices and homeomorphisms.

Course Contents:

1) **Prerequisites:** Vector Spaces: Definition and Examples, Subspaces, Bases and Dimensions, Linear Transformations, Quotient Spaces, Direct Sum, The matrix of Linear Transformation, Duality.
2) **Canonical Forms:** Eigenvalues and Eigenvectors, The minimal Polynomial, Diagonalizability, Triangular sable Operators, Jordan Forms, The Rational Forms.
3) **Inner Product Spaces:** Inner Product Spaces, Orthogonally, The Ad- joint of Linear Transformation, Unitary operators, Self-adjoint and Normal Operators.
4) **Bilinear Forms:** Definition and Examples, The matrix of a Bilinear Form, Orthogonality, Classification of Bilinear Forms.
5) **Applications:** Principal component analysis and its applications.(Optional)

Reference Books:

- Vivek Sahay, Vikas Bist, Linear Algebra.
- Sheldon Axler, Linear Algebra Done Right, 3rd Edition.
- Stephen Friedberg, Arnold Insel, Lawrence Spence, Linear Algebra, 5th Edition.
- Gilbert Strang, Linear Algebra and its applications, 5th Edition.
- David Lay, Steven Lay, Judi McDonald, Linear Algebra and Its Applications, 5th Edition.

MTS-103: Topology

Course Description:

The aim of this course is to introduce elementary properties of topological spaces, to develop the student's ability to handle abstract ideas of Mathematics, to understand and apply basic results about open and closed sets, continuous functions and homeomorphisms, connectedness, compactness, and separation axioms etc.

Course Objectives:

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

- understand concepts such as basis, open and closed sets, interior, closure and boundary etc.
- create new topological spaces by using subspace, product and quotient topologies etc.
- use continuous functions and homeomorphisms to know the structure of topological spaces.
- absorb concepts of connectedness, compactness, separability axioms and work out basic problems, proofs, provide examples and counter-examples etc.
- get acquainted with the Urysohn's lemma, the Tietze extension theorem and characterize metrizable spaces etc., to apply various concepts of topology to understand real world applications.

Course Contents:

1) **Prerequisites:** Cartesian Products, Finite Sets, Countable and Uncountable Sets, Infinite Sets and Axiom of Choice, Well Ordered Sets.
2) **Topological Spaces:** Basis for a topology, Order topology, Subspace Topology, Product topology, closed sets and limit points, Continuous functions, Metric Topology, Quotient spaces.
3) **Connected and Compact Spaces:** Connected spaces, Connected Subspaces of Real Line, Components and Local Connectedness, Compact spaces, Compact Subspaces of the Real Line, Limit point compactness, Local Compactness.
4) **Countability and Separation Axioms:** Countability Axioms, Separation axioms Normal Spaces, Urysohn's Lemma, Tietze Extension Theorem, Metrization Theorem, Tychonoff's Theorem.

Reference Books:

- J.R. Munkres, Topology: A First Course, (Prentice Hall, Second Edition), 2000.
- K. D. Joshi, Introduction to General Topology, Second Edition, New Age International.
- M. A. Armstrong, Basic Topology, Springer.

MTS-104: Programming with Python

Course Description:

The course "Programming with Python" introduces students to the fundamentals of programming using the Python programming language. The course covers the basics of Python syntax, data types, control structures, functions, file handling, object-oriented programming, web scraping, statistics, and data manipulation using libraries such as Matplotlib and Pandas. Students will learn how to write Python programs, solve problems, handle exceptions, work with web data, and perform data analysis using Python.

Course Objectives:

- To provide students with a solid foundation in Python programming, including syntax, variables, operators, and built-in functions.
- To familiarize students with essential data structures in Python, such as strings, lists, tuples, sets, and dictionaries, and their manipulation techniques.
- To introduce students to control structures, including conditional statements and loops, and their applications in solving programming problems.
- To teach students the concept of user-defined functions, modules, and libraries, enabling them to write modular and reusable code.
- To explore advanced topics such as exception handling, regular expressions, file handling, and package management in Python.
- To introduce students to object-oriented programming, including classes, objects, inheritance, and encapsulation.
- To provide students with an introduction to web scraping using Python and libraries such as Beautiful Soup for extracting data from websites.
- To familiarize students with data visualization using Matplotlib and data manipulation and analysis using Pandas.
- To introduce students to working with databases, specifically MongoDB, and performing CRUD operations using Python.
- To provide students with a basic understanding of web development using Python, including HTML templates, handling forms, user authentication, and interacting with databases.

Course Contents:

1) Introduction to Python, Variables, Built-in Functions, Operators
2) Strings - Strings, Python String Index, Slicing String in Python, String Methods,

   Lists – Lists, Python List Index, Slicing List in Python, List Methods,

   Tuples – Tuples, Modifying Tuple Elements, Tuple Methods,

   Sets- Sets, Modifying Set Items, Set Methods, Set Union & Intersection, Subset, SuperSet, Disjoint, Set difference & symmetric_difference,

   Dictionaries- Dictionary, Dictionary using for loop, Modifying Dictionary Items, Dictionary Methods, Conditionals Statements - Decision Making In Python, If, If Else, Nested If Else nested If,

   Loops - Why Loops?, For Loop, Range Function, While Loop, Nested Loop, Break Statement, Continue Statement, Else Class On Loop, Pass Statement

User defined Functions - Need For Functions, Function Definition, Function Arguments, Return Statement, Recursion In Python, Lambda Function,

Python Modules, List Comprehension, Higher Order Functions, Python Type Errors, Python Date time,

3) Exception Handling, Regular Expressions, File Handling, Python Package Manager
4) Classes and Objects, Inheritance
5) Introduction to Web Scraping using python - Beautiful Soup, Parsing our soup, Directional navigation, Image scraper, Improvements to our web scraper
6) Virtual Environment in python,
7) Statistics – Mathplotlib
8) Pandas – Introduction, Dataframes, Read CSV, Read JSON, Cleaning data, Corrections, Plotting
9) Python with MongoDB - Introduction and setup, Inserting documents, Bulk inserts, Counting documents, Multiple find conditions, Datetime and keywords, Indexes
10) Python web – Introduction, HTML templates, Building a MVC, Importing static files, Setting up a register form, Posting data to web.py, Creating users, Hashing passwords, Login logic, Web.py sessions, Logout functionality, Posting microblogs, Retrieving post objects, User settings and updating Mongo, Relative datetimes, Making our post dates pretty, Adding post comments, Image uploads and avatars

Reference Books:

- John V Guttag, Introduction to Computation and Programming Using Python, Prentice Hall of India, 2013.
- R. Nageswara Rao, Core Python Programming, Dreamtech Press, 2016.
- Wesley J. Chun(2006), Core Python Programming - Second Edition, Prentice Hall, 2006.
- Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser(2013), Data Structures and Algorithms in Pyhon, Wiley, 2013.
- Kenneth A. Lambert, Fundamentals of Python First Programs, CENGAGE Publication,2011.
- Luke Sneeringer, Professional Python, Wiley Inc.,2015.
- Mark Lutz, Learning Python, 3rd Edition, OReilly Media, Inc., 2007.
- Katharine Jarmul & Richard Lawson, Python Web Scraping - Paperback, (Packt Publishing Limited; 2nd Revised edition).

MT - RM - Research Methodology

Course Description:

The Research Methodology course is designed to equip students in Mathematics with the essential skills and knowledge required to conduct rigorous and effective research in their field. This course provides an overview of various research methods, techniques, and tools commonly used in mathematical research, with an emphasis on developing critical thinking, problem-solving abilities, and research ethics. Students will also gain hands-on experience in formulating research questions, designing experiments, analysing data, and presenting and writing research findings.

Course Objectives:

- To develop a comprehensive understanding of different research methodologies and their applications in mathematics.
- To cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.
- To provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.
- To foster effective communication skills for presenting research findings orally and in written form.
- To promote ethical research practices and awareness of responsible conduct in mathematical research.

Course Duration:

This course is typically spread over one semester, equivalent to approximately 15 weeks of instruction.

Course Outline:

Foundations of Research:

Meaning, Objectives, Motivation, Utility, Concept of theory, Research Problem Identification, Developing a Research Plan – Exploration, Description, Diagnosis, Experimentation, Determining Experimental and Sample Designs. Writing of Proofs, quantifiers etc.

Research Design:

Defining research objectives and questions, Analysis of Literature Review – Primary and Secondary Sources, Web sources for critical Literature Review such as MathSciNet, ZMATH, Scopus, Web of Science, Reviewing literature and identifying research gaps.

Research Methods:

Scientific methods, Logical Methods: Deductive, Inductive, logical methods. Quantitative research methods, Qualitative research methods, Data Collection Techniques, Surveys and questionnaires, Interviews and focus groups, Observations and case studies, Experimental methods, Data Analysis and Interpretation, Statistical analysis techniques in mathematics, Qualitative data analysis methods, Visualization and interpretation of results.

Research Writing and Presentation:

Scientific/ technical Writing Structure and Components, Importance of Effective Communication. Preparing Research papers for journals, Seminars and Conferences – Design of paper using TEMPLATE, Calculations of Impact factor of a journal, citation Index, ISBN & ISSN. Preparation of Project Proposal – Time frame and work plan – Budget and Justification – Preparation and Publication of Research paper, Thesis writing. Project Reports for various funding, Writing Statement of Purpose for PhD/Post Doc etc, Writing a review of paper, Presenting research findings orally and visually, Research Collaboration and

Communication, Collaborative research practices, Effective communication in mathematical research, Participating in conferences and seminars,

Research Ethics and Responsible Conduct:
Ethics and Ethical Issues – Ethical Committees – Commercialization – copy right – royalty – Intellectual Property rights and patent law – Track Related aspects of intellectual property Rights – Reproduction of published material – Plagiarism and software to detect plagiarism– Citation and Acknowledgement – Reproducibility and accountability.

Mathematical Software and Paraphrasing Software:
Basic Latex, Beamer, Overleaf, Grammarly, QuillBot, ChatGPT, and SAGE. Particularly, introduction to SAGE: Overview of the SAGE software, installation, and user interface. Basic Algebraic Manipulations: Symbolic algebra, equations, simplifications, and algebraic manipulations. Calculus Computations: Differentiation, integration. Linear Algebra with SAGE: Matrix operations, solving linear systems, eigenvalue calculations. Discrete Mathematics with SAGE: Combinatorics, graph theory, number theory, and cryptography.

Course Assessment:
The course assessment will include but not limited to a combination of the following methods:

- Research proposals and progress reports
- Research presentations
- Critical analysis of published mathematical research papers
- Participation in class discussions and activities
- Final research project or paper

Note: The syllabus provided above is a general outline and can be adapted and expanded based on the specific requirements of the institution offering this subject in Mathematics program and the expertise of the instructor.

References:

- C. R. Kothari, Research Methodology: Methods and Techniques. Second Edition. New Age International Publishers, New Delhi, 2008.
- Dilip Datta, LaTeX in 24 Hours, A Practical Guide for Scientific Writing, Springer
- Eva O. L. Lantsoght, The A-Z of the PhD Trajectory -A Practical Guide for a Successful Journey, Springer Cham, 2018.

MTS-201: Rings and Modules

Course Description:
This course is a study of Rings, Integral domains, Euclidean domains, Principal ideal domains, Unique factorization domains and theory of Modules.

Course Objectives:
On completion of the course, student will be able to,

- Understand and apply homomorphism and isomorphism theorems of rings
- Understand many examples of rings including non-commutative rings, integral domains and fields
- Check Irreducibility of polynomials, Uniqueness of factorizations in UFDs
- Understand basics of modules and their properties.
- Understand structure theorem of modules over PID and its implications

Course Contents:

1) **Rings, Ideals and Ring Homomorphisms:** Definition and examples, polynomial and power series rings, ring of integers and ring of Gaussian integers, ideals homomorphisms. Homomorphism theorems
2) **Euclidean domains**, Principal Ideal Domains and Unique Factorization Domains: Gauss' lemma, UFD property for polynomial rings, Gauss' theorem on Uniqueness of factorization in polynomial rings, irreducibility criteria, Eisenstein'scriterion, ring of cylclotomic integers.
3) **Modules:** Definition and examples, Bases and linear independence over rings, free and non-free modules, torsion freeness, modules over PID, Elementary divisors and Invariant Factors, Jordan and Rational Canonical form via modules over PID.

(Note: For modules over PID book by Steven Romanon Advanced Linear Algebra can be used.**)**

Reference Books:

- C. Musili, Rings and modules, Narosa, 1999.
- Steven Roman, Advanced Linear Algebra, 2nd Edition, Springer.
- Dummit D. and Foote R., Abstract Algebra, 2nd Edition, Wiley Eastern Ltd.
- Michael Artin, Algebra, 2nd Edition, Pearson, 2010.

MTS-202: Complex Analysis

Course Description:
This course is a study of analytic functions, power series, conformal mappings, complex integrations, singularities and the applications of these concepts.

Course Objectives:
On completion of the course, student will be able to understand

- The basics of complex numbers.
- Analytic functions, power series.
- Conformal mappings and applications.
- The theory of Complex integrations.
- Residue theorem and applications to real integrals.
- The importance of Maximum modulus theorem and its consequences.
- Aplications of Complex Analysis

Course Contents:

1) Stereographic projection, Elementary Functions, Exponential function, mapping properties, logarithmic function, complex exponents, branch of logarithm.
2) Mobius Transformations, Symmetry and orientation principle, Conformal mappings.
3) Analytic Functions: Cauchy-Riemann Equations, analyticity, harmonic functions, Power Series.
4) Complex Integration and Cauchy's Theorem, Cauchy's integral formula, Cauchy's estimate and applications, Homotopic version of Cauchy's theorem, Open mapping theorem, Gourasat's theorem
5) Singularities- Classification, Laurent series, Residue theorem and applications to evaluation of real integrals, Casorati-Weistrass theorem, Argument principle
6) Maximum modulus theorem, Schwarz's lemma
7) Applications of Complex Analysis in various fields

Reference Books:

- J. B. Conway, Functions of one complex variables, Narosa Publishing House, 1989.
- S. Ponnusamy, H. Silverman, Complex Variables with Applications, Birkhauser, 2006.
- J. Brown and R. Churchill, Complex variables and Applications, 8th Edition, McGraw-Hill, 2009
- M. Spiegel, S. Lipschutz, J. Schiller, D. Spellman, Schaum's Outline of Complex Variables, 2nd edition, 2009.

MTS-203: Measure and Integration

Course Descritpion:

This course is a study of concepts of measure, measurable functions, Lebesgue integration, Convergence theorems, L^2 spaces, product of measure spaces, applications of these concepts.

Course Objectives:

On completion of the course, student will be able to understand

- The concept of measure of a set.
- Properties of Lebesgue Measurable function.
- Lebesgue integrations and its relation with Riemann integration.
- Properties of L^2 spaces and applications
- Applications of measure and integration to probability theory

Course Contents:

1) Prerequisites: Cardinal Numbers and Countability, Properties of Open Sets, Cantor Like Sets.
2) Measure on Real Line: Lebesgue Outer Measure, Measurable Sets, Regularity, Measurable Functions, Borel and Lebesgue Measurability.
3) Integration of Functions on Real Variable: Integration of Non-Negative Functions, General Integral, Integration of Series, Riemann and Lebesgue Integral.
4) Differentiation: Functions of Bounded Variation, Lebesgue Differentiation Theorem, Differentiation Theorem, Differentiation and Integration.
5) Inequalities and L^P spaces: The L^P Spaces, The Convex Functions, Jensen's Inequalities, Inequalities of Holder and Minkowski's, Completion of L^P
6) Measure and integration on product spaces. Product of measure spaces, Integration on product spaces: Fubini's theorems, Lebesgue measure on R^2 and its properties
7) Applications: Applications of Measure and Integration to probability theory.

Reference Books:

- G. de Barra, Measure Theory and Integration, (New Age International Ltd), 1981.
- H. L. Roydon, Real Analysis, Third Edition, Prentice Hall, 1995.
- P.R. Halmos, Measure Theory, Graduate Text in Mathematics, Springer-Verlag, 1979.
- Inder K. Rana, An Introduction to Measure and Integration (2nd Edition), Narosa Publishing House, New Delhi, 2004.

- Marek Capi´nski and Ekkehard Kopp, Measure, Integral and Probability, Springer-Verlag, 1998.
- S. Kesavan, Measure and Integration, TRIM Series, Springer.

MTS-204: Programming with C++

Course Description:

The course "Programming with C++" introduces students to the fundamentals of object-oriented programming using the C++ programming language. It covers various aspects of C++ programming, including basic syntax, functions, object and classes, arrays and string arrays, operator overloading, inheritance, pointers, memory management, virtual functions, streams and files, and templates and exceptions. Through hands-on exercises and practical examples, students will gain proficiency in C++ programming and develop a strong understanding of object-oriented concepts.

Course Objectives:

- To understand the concepts and characteristics of object-oriented programming and the importance of using object-oriented languages like C++.
- To familiarize students with the basics of C++ programming, including output and input operations, type conversions, and manipulators.
- To explore functions in C++, including returning values, reference arguments, function overloading, inline functions, and default arguments.
- To provide a thorough understanding of objects and classes in C++, covering encapsulation, abstraction, polymorphism, class implementation, constructors, object as function arguments, copy constructors, and static class data.
- To introduce arrays and string arrays in C++, including their fundamentals and their usage as class member data.
- To explore the concept of operator overloading in C++, covering unary and binary operators, data conversion, pitfalls, and conversion keywords.
- To understand the concept of inheritance in C++, including derived classes, base classes, constructors, member functions, class hierarchies, and aggregation.
- To develop a strong understanding of pointers in C++, including addresses, pointer operations, arrays, fractions, and C-style strings.
- To cover memory management techniques in C++, including dynamic memory allocation using the new and delete operators, pointers to objects, and debugging pointers.
- To introduce virtual functions, friend functions, static functions, assignment and copy initialization, this pointer, and dynamic type information in C++.
- To explore streams and file handling in C++, including stream classes, disk file I/O, error handling, overloading extraction and insertion operators, handling command line arguments, and printer output.
- To introduce templates and exceptions in C++, covering function templates, class templates, and exception handling techniques.

Course Contents:

1) **Introduction:** What is object oriented programming? Why do we need object oriented programming characteristics of object-oriented languages C and C++.

2) **C++ Programming basics:** Output using cout. Directives. Input with cin. Type bool. The setw manipulator. Type conversions.
3) **Functions:** Returning values from functions. Reference arguments. Overloaded function. Inline function. Default arguments. Returning by reference.
4) **Object and Classes:** Making sense of core object concepts (Encapsulation, Abstraction, Polymorphism, Classes, Messages Association, Interfaces) Implementation of class in C++, C++ Objects as physical object, C++ object as data types constructor. Object as function arguments. The default copy constructor, returning object from function. Structures and classes. Classes objects and memory static class data. Const and classes.
5) **Arrays and string arrays fundamentals. Arrays as class Member Data:** Arrays of object, string, The standard C++ String class
6) **Operator overloading:** Overloading unary operations. Overloading binary operators, data conversion, pitfalls of operators overloading and conversion keywords. Explicit and Mutable.
7) **Inheritance:** Concept of inheritance. Derived class and based class. Derived class constructors, member function, inheritance in the English distance class, class hierarchies, inheritance and graphics shapes, public and private inheritance, aggregation: Classes within classes, inheritance and program development.
8) **Pointer:** Addresses and pointers. The address of operator and pointer and arrays. Pointer and Faction pointer and C-types string.
9) **Memory management:** New and Delete, pointers to objects, debugging pointers.
10) **Virtual Function:** Virtual Function, friend function, Static function, Assignment and copy initialization, this pointer, dynamic type information.
11) **Streams and Files:** Streams classes, Stream Errors, Disk File I/O with streams, file pointers, error handling in file I/O with member function, overloading the extraction and insertion operators, memory as a stream object, command line arguments, and printer output.
12) **Templates and Exceptions:** Function templates, Class templates Exceptions

Reference Books:

- C++ Primer Plus, Stephen Prata, Pearson Publications.
- Programming in C++, Ashok Kamthane, Pearson Publications.
- Introduction to Programming with C++, Y. Daniel Liang, Pearson Publications.
- The C++ Programming Language, B. Stroustrup Addison-Wesley Publications.

MTS-301: Functional Analysis

Course Description:
The course "Functional Analysis" provides an in-depth study of function spaces and their applications. It explores normed linear spaces, linear functionals, Banach spaces, Hilbert spaces, and important theorems related to these spaces. The course aims to develop a strong understanding of the properties and structures of these spaces, as well as their applications in various areas of mathematics and other disciplines.

Course Objectives:

- Understand the concept of normed linear spaces and their properties.
- Analyze the continuity of linear maps between normed linear spaces.
- Explore linear functionals and their significance in functional analysis.
- Apply the Hahn-Banach Theorems and related extension theorems.
- Understand the concept of Banach spaces and their key properties.
- Apply the Uniform Boundedness Principle and related theorems.
- Investigate the Closed Graph Theorem, Open Mapping Theorem, and Bounded Inverse Theorem.
- Gain proficiency in Hilbert spaces and their properties.
- Explore orthonormal sets and their significance in Hilbert spaces.
- Understand the concept of projections and their applications.
- Comprehend the Riesz representation Theorem and its implications.

Course Contents:

1) Motivation for functional analysis and introduction to normed linear spaces.
2) Study of continuity of linear maps between normed linear spaces.
3) Exploration of linear functionals and the Hahn-Banach Theorems.
4) Introduction to Banach spaces and the Uniform Boundedness Principle.
5) Investigation of the Closed Graph Theorem, Open Mapping Theorem, and Bounded Inverse Theorem.
6) Introduction to Hilbert spaces and their properties.
7) Study of orthonormal sets in Hilbert spaces.
8) Understanding projections and their applications.
9) Exploration of the Riesz Representation Theorem and its consequences.
10) Through this course, students will develop a strong foundation in functional analysis, which will enable them to understand and analyze various function spaces and their applications in mathematics and other disciplines. They will also gain the ability to apply important theorems and techniques in functional analysis to solve problems and conduct further research in related fields.

Reference Books:

- G. F. Simmons, Introduction to Topology and Modern Analysis, (McGraw Hill), 2003.
- Balmohan Limaye, Functional Analysis, 2nd Edition.
- John B. Conway, A Course in Functional Analysis, Springer, 1997.
- Karen Saxe, Beginning Functional Analysis, Springer, 2000.
- Be´la Bollaba´s, Linear Analysis, 2nd Edition, CUP, 2018.

MTS-302: Advanced Calculus

Course Description:

This course is a study of Chain rule, Inverse function theorem, Implicit function theorem, integral over a rectangle, existence of the integral, integral over a bounded set, and rectifiable sets, improper integral, partitions of unity, change of variables theorem with applications, line integrals with applications.

Course Objectives:

On completion of the course, student will be able to understand

- the concepts of functions of severable variables.
- the inverse function theorem, which gives conditions under which a differentiable function from R^n to R^n has a differentiable inverse, and the implicit function theorem, which provides the theoretical underpinning for the technique of implicit differentiation as studied in calculus.
- the concept of integral over a rectangle, a bounded set and rectifiable sets.
- the concept of partitions of unity, change of variables theorem with applications, line integrals with applications.

Course Contents:

1) **Differentiation:** Derivative, Continuously Differentiable functions, Chain rule, Inverse function theorem, Implicit function theorem.
2) **Integration:** integral over a rectangle, existence of the integral, evaluation of the integral, integral over a bounded set and rectifiable sets, improper integrals
3) **Change of Variables Theorem:** partitions of unity, Change of Variables theorem, applications of Change of Variables theorem, Line integrals with applications

Reference Books:

- J. R. Munkres, Analysis on Manifolds, 3rd Edition, Addition-Wesley.
- Michael Spivak, Calculus on Manifolds, Benjamin Cummings, 1965.
- Girald B. Folland, Advanced Calculus, Person, 2011.

MTS-303: Graph Theory

Course Description:
The course "Graph Theory" introduces students to the fundamental concepts, tools, and techniques of graph theory. It covers various classes of graphs, including bipartite graphs, Eulerian graphs, and trees, along with their applications in computer science. Students will learn about algorithms, spanning trees, matchings, and factors, as well as their relevance and significance in real-world scenarios.

Course Objectives:
- To understand the aims and objectives of Graph Theory.
- To familiarize students with mathematical tools and techniques used in graph theory.
- To explore the concepts of Eulerian graphs, trees, and their applications in computer science.
- To learn techniques for independent sets, vertex covers, matchings, and factors in graphs.

Course Contents:
1) **Fundamental Concepts:** Basic definitions and examples of paths, cycles, walks, trails etc, Bipartite graphs and characterization, Eulerian graphs and characterization, Degree sum formula, counting and bijection, hypercubes, directed graphs, orientations
2) **Trees :** Trees and its properties, spanning trees, enumeration of trees, Matrix tree theorem, Minimum spanning tree, Kruskal's algorithm and Dijkstra's algorithm, Trees in Computer Science.
3) **Matchings and Factors:** Notions of matching, perfect matching, Halls theorem, Independent sets and covers
4) **Connectivity:** Vertex, Edge connectivity, Menger's Theorem.

Reference Books:

- Douglas B. West, Introduction to Graph Theory, 2nd Edition, Prentice Hall.
- R. J. Wilson, Introduction to Graph Theory, Pearson, 2003.
- John Clarke and D.A. Holton, A First Look at Graph Theory, Allied Publisher, 1991.
- Nora Harsfield and Gerhard Ringel, Pearls Theory, Academic Press, 1990.
- Harary, Graph Theory, Narosa Publishers, New Delhi, 1989.
- R. B. Bapat, Graphs and Matrices, 2nd Edition, Hindustan Book Agency.

MTS-304: Differential Equations

Course Descritption:
This course is a study of concept of different types linear and nonlinear differential equations of one and two dimensions such as the Lorenz model and quadratic ordinary differential equations. Moreover, this course also aims to study the existence and uniqueness theorem of solution of differential equations.

Course Objectives:

On completion of the course, student will be able to:

- Classify the types of differential equations
- Understand the fundamental solution theorem
- Understand the existence and uniqueness theorem
- Apply the method of successive approximations to solve differential equations
- Apply the method of Frobenius to solve differential equations
- Solve particular examples and exercises of differential equations

Course Contents:

1) Prerequisites: Linear equations of the first order, Linear equations with constant coefficients,
2) Linear equations with variable coefficients: Initial value problems, Solutions of the homogeneous equation, Wronskian and linear independence, Reduction of order, Non-homogeneous equations, Homogeneous equations with analytic coefficients, Legendre equation.
3) Linear Equations with regular singular points: Euler equation, Second order equation with regular singular points, Exceptional cases, Bessel's equation.
4) Existence and uniqueness of solutions to first order equations: Separation of variables, exact equations, Method of successive approximations, Lipschitz condition, approximation to and uniqueness of solutions.
5) Existence and uniqueness of solutions to systems and n-th order equations: Complex n-dimensional space, Systems as vector equations, Existence and uniqueness of solutions to systems, Uniqueness for linear systems and equations of order n.

Reference Books:

- E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice- Hall.
- G. F. Simmons and S. G. Krantz, Differential Equations, Tata McGraw-Hill.

MTS-401: Partial Differential Equations

Course Descritption:

This course is a study of the concept of different types of partial differential equations (PDEs) such as first-order differential equations, second-order differential equations, Laplace equations, and heat equations. and wave equations and solve them using well-known methods such as the method of characteristics and separation of the variable method.

Course Objectives:

On completion of the course, students will be able to

- Understand the basics of partial differential equations.
- Apply the method of characteristics to solve types of PDEs.
- Apply the method of variables separation.
- Solve particular examples of PDEs.

Course Contents:

(1) First and second-order linear equations: terminologies, superposition principle, linear dependence, First order linear equations, initial value problem, classification of second-order equations, well-posedness
(2) Heat equation: Derivation of the heat equation, initial boundary value problems, homogeneous boundary conditions, non-homogeneous boundary conditions, Robin boundary conditions, Infinite domain problems, maximum principle, energy method, and uniqueness of solutions.
(3) Wave equation: Derivation of the wave equation, Initial value problems, wave reflection problems, Initial boundary value problems, Energy method
(4) Laplace equation: boundary value problems, separation of variables, Fundamental solution, Green's identity, Green's function, Properties of harmonic function, Well-posedness issues
(5) First-order quasilinear equations, scalar conservation law, Rankine-Hugoniot condition, weak solutions, entropy condition, traffic flow problem, First order nonlinear equations, systems of first-order equations.
(6) Fourier series and Eigenvalue problems: Fourier convergence theorems, Derivations of Fourier series, Sturm-Lowville Problems.

Reference Books:

- H. Hattori, Partial Differential Equations, Methods, Applications and Theories, World Scientific publications, 2014.
- T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa, 2003.
- J. Brown and R.V. Churchill, Fourier Series, and Boundary Value Problems, (McGraw- Hill)

MTS-402: Advanced Linear Algebra

Course Description:

Advanced Linear Algebra is course that builds on the previous knowledge of Linear Algebra and gives students a flavour of applications of Linear Algebra. Some of the concepts covered under this course could be Markov chains, Singular Value Decompositions(SVD) and applications of Linear Algebra such as Google page rank algorithm. Under this course spectral theory of matrices can be covered with emphasis on graphs and matrices. Some of important class of matrices such as adjacency matrix, incidence matrix Laplacian matrix can be discussed.

Course Objectives:

- To understand the relevance and significance of linear algebra
- To understand how Linear Algebra comes to be applied in various fields such as graph theory
- Understand basic techniques such as Perron-Frobenuis theory and its implications to graph theory

Course Contents:

Diagonalization and spectral theorem of symmetric matrices, Cauchy's interlacing theorem and applications to adjacency matrices of graphs, Perron-Frobenius theory and spectral values of graphs, Laplacian matrix and incidence matrix of graphs, Orthogonal decomposition, Singular Value Decomposition (SVD), Markov chains and graphs, Google page-rank algorithm and its variants

Reference Books:

- Foundations of Data Science, A. Blum, J. Hopcroft, and R. Kannan, Hindustan Book Agency
- R. B. Bapat, Graphs and Matrices, 2nd Edition, Hindustan Book Agency.
- Steven Roman, Advanced Linear Algebra, Springer Verlag.
- Peter Lax, Linear Algebra, Joh Wiley & Sons.
- Audrey Terras, Zeta Functions of Graphs, Cambridge University Press.

MTS-403: Number Theory

Course Description:
This course is a study of properties of positive numbers, in particular prime numbers, solve congruence problems using modular arithmetic, and laws of quadratic reciprocity. Further, the course covers the study of arithmetic functions and introduces the student to higher topics in number theory such as algebraic numbers. Finally course discusses solutions to some Diophatine equations

Course Objectives:

- To develop basic understanding of fundamental problems in Number Theory
- To understand the basic approaches and techniques in Number Theory
- To develop an understanding of the main problems of Number Theory
- To understand the basic tools and techniques in Number Theory
- To appreciate the role of quadratic reciprocity laws from the modern point of view.

Course Contents:
Uniqueness of factorization in integers and Gaussian integers, failure of uniqueness of factorization in integral domains, Arithmetical functions and Quadratic reciprocity, Rings of algebraic integers and number fields, concept of norm, quadratic and cyclotomic fields, Diophantine equations such as Pell's equation, Brahmagupta's Chakraval method to solve Pell's equation

Reference Books:

- Alan Baker, Comprehensive Introduction to Number Theory, Cambridge University Press.
- K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd Edition, Springer.
- I. Niven, H. Zuckerman, H. Montgomery, An introduction to the Theory of Numbers, 5th Edition.
- Ian Stewart and David Tall, Algebraic Number Theory and Fermats Last Theorem, A K Peters Ltd, 3rd Edition.
- B.Sury , Chakravala - A modern Indian Method (Article)
- Amartya Kumar Dutta, Mathematics in Ancient India, Resonance (Article)

Syllabus for Elective Courses

MTE-1 Numerical Analysis

Course Description:

The course "Numerical Analysis" focuses on various numerical methods used for solving mathematical problems and approximating solutions. It covers topics such as solving algebraic and transcendental equations, interpolation, numerical differentiation and integration, numerical linear algebra, and numerical solutions of ordinary differential equations.

Course Objectives:

- To understand and apply different numerical methods for solving algebraic and transcendental equations.
- To learn interpolation techniques for approximating unknown values within a set of given data points.
- To explore numerical differentiation and integration methods for approximating derivatives and integrals.
- To study numerical techniques for solving systems of linear equations and understand their computational aspects.
- To learn numerical methods for approximating solutions to ordinary differential equations.

Course Contents:

1) **Solution of Algebraic And Transcendental Equations:** Introduction, The Bisection Method, The Method of False Position, The Iteration Method, Newton-Raphson Method, Generalized Newton's Method, Ramanujan's Method, Muller's Method.
2) **Interpolation:** Introduction, Finite Differences, Forward Differences, Backward Differences, Central Differences, Symbolic Relations and Separation of Symbols, Differences of a Polynomial, Newton's Formula for Interpolation, Central Difference Interpolation Formula, Gauss's Central Difference Formula, Sterling's and Bessel's formula, Lagrange's Interpolation Formula, Hermite's Interpolation formula, Divided Differences and their properties, Newton's General Interpolation Formula.
3) **Numerical Differentiation and Integration:** Introduction, Numerical Differentiation- Cubic spline method, Numerical Integration-Trapezoidal Rule, Simpson's 1/3 rule, Simpsons 3/8 Rule, Boole's and Weddle's Rules, Euler-Maclaurin formula, Numerical Double Integration.
4) **Numerical Linear Algebra:** Matrix Norms, Exact methods: LU-decomposition, Gauss-elimination methods without and with partial pivoting. Iterative methods: Gauss-Jacobi and Gauss Seidal methods.
5) **Numerical Solutions Of Ordinary Differential Equations:** Taylor's Series method, Picard's Method, Euler's method, Runga-Kutta method.

Reference Books:

- S. S. Sastry, Introductory Methods of Numerical Analysis, PHI, 2021.
- M.K. Jain, S.R.K. Iyengar, R.K. Jain, Numerical Methods for Scientific & Engineering
- Computations, New Age International Publishers, 2012.
- K.E. Atkinson, An Introduction to Numerical Analysis, Second Edition, John Wiley & Sons, 1988.
- J. I. Buchaman, P. R. Turner, Numerical Methods and Analysis, McGraw Hill,1992.
- S. Arumugam, Isaac A. Thangapandi, A. Somasundaram, Numerical Methods for Scientists and Engineers, SciTech Publications, Numerical Methods, 2012.

MTE-2: Combinatorics

Course Description:

Combinatorics is a course that focuses on the study of counting methods, generating functions, recurrence relations, inclusion-exclusion principle, and Ramsey theory. The course explores various techniques and concepts in combinatorics and their applications in solving problems related to arrangements, selections, partitions, and geometrical problems.

Course Objectives:

- To provide a foundation in basic counting principles and techniques for arrangements and selections, including combinations and permutations.
- To understand and apply counting methods for arrangements and selections with repetition and distributions.
- To introduce and explore generating functions as a powerful tool for solving combinatorial problems and calculating coefficients.
- To study partitions and exponential generating functions and their applications in combinatorial problems.
- To understand and solve recurrence relations using techniques such as divide and conquer and generating functions.
- To introduce the inclusion-exclusion principle and its application in counting problems, including restricted positions and rook polynomials.
- To explore Ramsey theory and its applications in solving geometrical problems, focusing on the Ramsey theorem.

Course Contents:

1) **Counting Methods for selections arrangements:** Basic counting principles, simple arrangements and selections, arrangements and selection with repetition, distributions, binomial, generating permutations and combinations and programming projects.
2) **Generating functions:** Generating function models, calculating of generating functions, partitions exponential generating functions, a summation method.
3) **Recurrence Relations:** Recurrence relation model, divide and conquer relations, solution of inhomogeneous recurrence relation, solution with generating functions.
4) **Inclusion-exclusion:** Counting with Venn diagrams inclusion formula, restricted positions and rook polynomials.
5) **Ramsey Theory:** Ramsey theorem, applications to geometrical problems.

Reference Books:

- Alan Tucker, Applied Combinatorics 3rd Edition, John Wiley & Sons, New York, 1995.
- V. Krishnamurthy, Combinatorial, Theory and Applications, East West Press, New Delhi, 1989.

MTE-3: Operation Research

Course Description:

Operations Research is a course that focuses on the application of mathematical modeling and optimization techniques to solve complex decision-making problems. The course covers linear programming (LP), simplex method, sensitivity analysis, duality, transportation and assignment models, network models, advanced linear programming, and integer linear programming. Students will learn how to formulate and solve optimization problems using various techniques and algorithms.

Course Objectives:

- To introduce students to the concept of mathematical modeling in operations research.
- To provide an understanding of linear programming models and their graphical solutions.
- To explore the simplex method as an algorithm for solving linear programming problems.
- To introduce sensitivity analysis and its role in evaluating the robustness of solutions.
- To understand duality in linear programming and its economic interpretation.
- To study transportation and assignment models and their solution algorithms.
- To introduce network models and solve problems related to minimal spanning trees, shortest paths, maximal flow, CPM, and PERT.
- To explore advanced topics in linear programming, including the revised simplex method and bounded variable algorithm.
- To introduce integer linear programming and illustrate its applications through case studies.
- To develop problem-solving and analytical skills through real-world applications and optimization algorithms.

Course Contents:

1) **Modeling with Linear Programming:** Two variable LP model, graphical LP solutions, selected LP applications.
2) **Simplex method and Sensitivity Analysis:** LP model in equation form, transition from graphical to algebraic solution, simplex method, artificial starting solution, special cases in the simplex method, sensitivity analysis.
3) **Duality and Post-Optimal Analysis:** Definition of the dual problem, primal dual relationships, economic interpretation of duality, additional simplex algorithms.
4) **Transportation Model and its Variants:** Definition of the transportation model, non traditional transportation models, transportation algorithm, assignment model.
5) **Network Model:** Scope and de_nition of network models, minimal spanning tree algorithm, shortest root problem, maximal ow model, CPM and PERT.
6) **Advanced Linear Programming:** Simplex method fundamentals, revised simplex method, bounded variable algorithm, duality.
7) **Integer Linear programming:** Illustrative applications, integer programming algorithms.

NB : Use suitable mathematical software to solve relevant problems.

Reference Books:

- Hamy A.Taha, Operations Research, 8th Edition, Prentice Hall of India, 2008.

- J. K. Sharma, Operations Research, 3rd Edition, Macmillan India Ltd., 2008.
- P. K. Gupta and D. S. Haria, Operations Research, 5th Edition, S. Chand, 2014.

MTE-4: Differential Equations And Dynamical Systems

Course Description:

Linear and Nonlinear Systems is a course that covers both linear and nonlinear systems of differential equations. The course begins with a focus on linear systems, including uncoupled linear systems, diagonalization, exponential of operators, fundamental theorem for linear systems, stability theory, and nonhomogeneous linear systems. It then transitions to nonlinear systems, exploring local theory, fundamental existence theorem, flow defined by a differential equation, linearization, stable manifold theorem, Hartman-Grobman theorem, stability and Lyapunov functions, and various types of critical points in Rn.

Course Objectives:

- To develop an understanding of linear systems of differential equations and their properties. Further, to explore the concepts of uncoupled linear systems, diagonalization, and exponential of operators.
- To understand the fundamental theorem for linear systems, their stability theory and its applications. Also, to analyze complex eigenvalues, and Jordan Canonical Form.
- To introduce nonlinear systems of differential equations and their behavior.
- To explore the local theory of nonlinear systems and the dependence on initial conditions and parameters.
- To study the maximal interval of existence and the flow defined by a differential equation.
- To understand the process of linearization and its applications in studying nonlinear systems.
- To explore stability and Lyapunov functions and their role in analyzing the behavior of nonlinear systems.
- To study different types of critical points in Rn, including saddles, nodes, foci, and Hamiltonian systems and their properties.

Course Contents:

1) **Liner Systems:** Uncoupled Liner Systems, Diagonalization, Exponential of operators Fundamental theorem for liner systems, liner systems in R, Complex eigenvalues, multiple eigenvalues,jorden Canonical Forms, stability theory Nohomogeneous Liner systems.

2) **Nonlinear Systems:** Local Theory, Fundamental existence theorem dependence on initial conditions and parameters, the maximal interval of existence, Flow defined by a differential equation. Linearization, stable manifold theorem, Hartman- Grobman theorem, Stability and Lipunov functions, Saddles, Nodes, Foci and centers, Nonhyperbolic critical points in Rn, Gradient and Hamiltonian system.

Reference Books:

- L. Perko- Differential Equations and Dynamical systems, Springer-verlag, 1991.
- Hirsch and Smale – Differential Equations, Dynamical Systems, and Liner Algebra - Academic Press, New York, 1974.

MTE-5: Representation Theory

Course Description:

Group Theory and Representations is a course that focuses on the study of group actions, group representations, irreducible and indecomposable representations, Maschke's theorem, Schur's lemma, characters and class functions, the regular representation, permutation representation, representations of Abelian groups, Fourier analysis on finite groups, convolutions, applications to graph theory, Burnside's theorem, and optionally, induced representations. The course provides a solid foundation in group theory and its applications in various areas of mathematics and related fields.

Course Objectives:

- To introduce the fundamental concepts of group theory, including group actions and representations.
- To study irreducible and indecomposable representations and their properties.
- To understand Maschke's theorem and complete reducibility of representations.
- To analyze Schur's lemma and its applications in the theory of representations.
- To study orthogonality relations, characters, class functions of group representations, the regular representation and permutation representation.
- To understand the representations of Abelian groups and their properties.
- To introduce Fourier analysis on finite groups and its applications.
- To study convolutions and their role in group representations.
- To explore the applications of group representations in graph theory.
- To study Burnside's theorem, which relates group actions to counting problems.

Course Contents:

Group actions, basic definitions and examples of group representations, irreducible and indecomposable representations, Maschke's theorem and complete reducibility, schur's lemma, orthogonality relations, characters and class functions, the regular representation, permutation representation, representations of Abelian groups, Fourier analysis on finite groups, convolutions, applications to graph theory, Burnside's theorem, Induced Representations (Optional).

Reference Books:

- Benjamin Steinberg, Representation Theory of Finite Groups
- J. P. Serre, Linear Representations of Groups
- James Leibeck, Representation Theory
- Michael Artin, Algebra.

MTE-6: Computational Geometry

Course Description:
Computational Geometry is a course that focuses on the study of geometric transformations, projections, curves, Bezier curves, B-splines, and various algorithms used in computational geometry. The course explores concepts and techniques used in computer-aided design, curve rendering, conics, curve parametrization, and applications of geometric algorithms in problems such as collision detection, closest pair problem, convex hull, smoothing, line segment intersection, nesting, point location, triangulation, and bounding box.

Course Objectives:
- To provide a review of transformations of the plane, including translations, reflections, rotations, shears, and their applications.
- To introduce homogeneous coordinates and their use in projective geometry and transformations. Further, to study projections, including parallel projection and perspective projection, and their types.
- To explore curve rendering techniques and the parametric representation of curves.
- To classify conics and understand their intersections with lines.
- To study Bezier curves of various degrees, including linear, quadratic, cubic, and general Bezier curves, and their properties.
- To introduce rational Bezier curves and their applications. Further, to explore B-splines, their properties, and their types, with applications in font design.
- To understand and analyze algorithms used in computational geometry, including the closest pair problem, collision detection, convex hull algorithms (Graham Scan, Gift Wrapping, Chan's), smoothing algorithms, line segment intersection algorithms, nesting algorithm, point location with respect to a polygon, triangulation, and bounding box algorithms.

Course Contents:
1) **Revision:**
    a. **Transformations of the Plane:** Translations, reflections, rotations, shears, con-
    b. catenation of transformations, applications, Homogenous coordinates: Homogenous coordinates, points at infinity, projective plane, transformations in homogenous coordinates,
    c. **Transformations of the Space:** Translations, scaling, reflection, rotation about coordinate axes, rotation about an arbitrary line, reflection in an arbitrary plane, applications to Computer-aided Design.
2) **Projections:** Parallel projection and its types, Perspective projection and its types.
3) **Curves:** Curve rendering, parametric Curves, arclength and reparameterization,
    a. Classification of Conics, Intersections of a Conic with a Line, parametrization of
    b. an irreducible conic, Conics in space, applications of conics.
4) **Bezier Curves:** Bezier curves of low degree, linear Bezier curves, quadratic Bezier
    a. curves, cubic Bezier curves, the general Bezier curve, properties of the Bernstein
    b. polynomials, properties of Bezier curves, The de Casteljau Algorithm and applications, Rational Bezier Curves and its properties and applications.
5) **B-splines:** Introduction to B-splines, properties of the B-spline Curve and its types, application to Font Design.
6) **Algorithms:** Closest pair problem, Collision detection, Convex hull algorithms (Graham Scan, Gift Wrapping, Chan’s), Smoothing algorithms, Line segment intersection algorithms, Nesting algorithm, Position of a point with respect to polygon, Triangulation, Bounding box algorithm.

Reference Books:

- Duncan Marsh, Applied Geometry for Computer Graphics and CAD, 2nd Edition, Springer.
- de Berg, van Kreveld, Overmars, and Schwarzkopf, Computational Geometry Algorithms and Applications, 2nd Edition, Springer-Verlag, 2000.

MTE-7: Lattice Theory

Course Description:

Lattice Theory is a course that focuses on the study of lattices, congruence relations, homomorphisms, isotone maps, ideals, complements, modular lattices, and various characterization and representation theorems in lattice theory. The course explores the fundamental concepts and properties of lattices, their structure, and the relationships between different types of lattices. The course also covers topics such as distributive modular inequalities, join and meet-irreducible elements, and semi-modular lattices.

Course Objectives:

- To introduce the definitions and properties of lattices and their representation using Hasse diagrams.
- To explore the concepts of homomorphism, isotone maps, ideals, and congruence relations in lattices.
- To study the homomorphism theorem, product of lattices, complete lattices, and ideal lattices.
- To analyze distributive modular inequalities, complements, pseudocomplements, and the Boolean lattice of pseudocomplements.
- To understand irreducible elements and their role in lattice theory.
- To explore characterization theorems and representation theorems in lattice theory, such as Dedekind's modularity criterion, Birkhoff's distributivity criterion, and Stone's theorems.
- To study modular lattices and their isomorphism theorem, as well as the upper and lower covering conditions.
- To understand Kurosh-Ore theorem, independent sets, and their applications in lattice theory.
- To explore semi-modular lattices and concepts such as the Jordan-Holder chain condition, modular pairs, and M-symmetric lattices.

Course Contents:

1) Two definitions of lattices, Hasse diagrams, homomorphism, isotone maps, ideals, congruence relations, congruence lattices, the homomorphism theorem, product of lattices, complete lattice, ideal lattice, distributive modular inequalities and identities, complements, pseudocomplements, Boolean lattice of pseudocomplements, join and meet-irreducible elements.
2) Characterization theorems and representation theorems-Dedekind`s modularity criterion Birkhov`s distributivity criterion, hereditary subsets, rings of sets, Stone theorems, Nachbin theorem, statements of Hashimotos theorem.
3) Modular lattices, isomorphism theorem, Upper and lower covering conditions, Kuros-Ore theorem, independent sets (Drops results involving projectivity and sublattice generated by sets /elements)
4) Semi-modular lattices Jordan-Holder chain condition, Modular pair, M-sysmmetric lattices.

Reference Books:

- G. Gratzer, General Lattice Theory, 2nd Edition, Birkhauser, 1998.
- B. A. Davey, H. A. Priestley, Introduction to Lattices and Order, 2nd Edition, Cambridge.
- Vijay K. Garg, Introduction to Lattice Theory with Computer Science Applications, Wiley.

MTE-8: Boundary Value Problems

Course Description:

Boundary Value Problems is a course that focuses on the study of boundary value problems and their applications in various areas of mathematics and physics. The course covers topics such as the heat equation, wave equation, Laplace's equation, Fourier method, separation of variables, Sturm-Liouville problems, orthogonal sets of functions, generalized Fourier series, Bessel functions, Legendre polynomials, and their applications in solving boundary value problems. The course provides a solid foundation in the theory and techniques used to solve boundary value problems.

Course Objectives:

- To introduce the concept of boundary value problems and their significance in mathematical and physical applications.
- To study specific boundary value problems, including the heat equation, wave equation, and Laplace's equation.
- To explore the Fourier method and its application in solving boundary value problems.
- To understand linear operators and the principle of superposition in solving boundary value problems.
- To analyze series solutions and the concept of uniform convergence using the Weierstrass M-test.
- To explore separation of variables as a technique for solving partial differential equations in different coordinate systems.
- To study nonhomogeneous boundary conditions and their impact on the solutions of boundary value problems.
- To introduce Sturm-Liouville problems and their applications.
- To understand orthogonal sets of functions and their properties, including generalized Fourier series and best approximation in the mean.
- To explore specific orthogonal sets of functions, such as orthonormal trigonometric functions, Legendre polynomials and to study Bessel functions and properties, including recurrence relations and zero values.
- To analyze Fourier-Bessel series and their applications in solving boundary value problems, such as temperature distribution in a long cylinder.

Course Contents:

1) Definition of boundary Value Problems, the heat equation, wave equation, Laplace’s equation, the Fourier method, Liner Operators, Principal of Superposition, series solutions, uniform convergence (weierstrass M-test), separation of variables, non homogeneous conditions, Sturm-Liouville problems, formal solutions, the vibrating string.
2) Orthogonal sets of functions, Generalized Fourier series, Best approximation in the mean, Convergence in the mean, the orthonormal trigonometric functions, other types of orthogonality.
3) sturm-Liouville Problem and applications, orthogonality and uniqueness of eigenfunctions, method of solutions, surface heat transfer other boundary value problems.
4) Bessel function Jn, recurrence relation, the zero of Jo (X) and related functions, Fourier-Bessel series, Temperatures in a long cylinder.

5) Legendre polynomials, orthogonality of Legendre polynomials, Legendre series, Dirichlet Problem in spherical regions.

Reference Books:

- R. V. Churchill and J. Brown.: Fourier Series and Boundary Value Problems, 4^{th} Edition, McGraw-Hill Book Company.

MTE-9: Commutative Algebra

Course Description:
The course "Commutative Algebra" provides an in-depth study of fundamental concepts and techniques in commutative algebra. The course explores various algebraic structures, such as rings and modules, and their properties. It covers topics like ideals, quotient rings, modules and submodules, tensor products, localization, chain conditions, primary decomposition, integral dependence, and valuations. The course emphasizes the theoretical foundations and applications of commutative algebra in various branches of mathematics.

Course Objectives:

- Understand the fundamental concepts of commutative algebra, including rings, ideals, and modules.
- Explore the properties of rings and modules, such as zero-divisors, prime ideals, maximal ideals, and radicals.
- Study quotient rings and module homomorphisms, and their connections to factorization and isomorphism theorems.
- Learn about operations on ideals and their applications in solving algebraic problems.
- Investigate the structure and properties of finitely generated modules, exact sequences, and tensor products.
- Develop an understanding of chain conditions, primary decomposition, and the properties of Noetherian and Artinian rings.
- Gain knowledge of integral dependence, going-up and going-down theorems, and integrally closed integral domains.
- Explore valuation rings and their applications in algebraic number theory and algebraic geometry.

Course Contents:

1) **Rings and Ideals:** Rings and ring homomorphisms, ideals. Quotient rings, Zero-divisors. Nilpotent elements, Prime ideals and maximal ideals, nilradical and Jacobson radical, Operations on ideals, Extension and contraction
2) **Modules:** Modules and module homomorphisms Submodules and quotient modules Operations on submodules. Direct sum and product Finitely generated modules Exact sequences, Tensor product of modules Restriction and extension of scalars Exactness properties of the tensor product Algebra.
3) **Rings and Modules of Fractions:** Local properties, Extended and contracted ideals in rings of fractions. Ascending and descending chain conditions, Primary decomposition of ideals, Primary ideals, Noetherian rings, Artinian rings.
4) **Integral Dependence and Valuations:** Integral dependence, The going-up theorem, integrally closed integral domains, The going-down theorem, Valuation rings.

Reference Books:

- M. F. Atiyah and I. G. Macdonald, Introduction to commutative algebra,
- N. S. Gopalkrishnan, Commutative Algebra

MTE-10: Matroid Theory

Course Description:

Matroid Theory is a course that focuses on the study of matroids, which are combinatorial structures that generalize the concept of linear independence in vector spaces and the concept of spanning trees in graphs. The course covers topics such as independent sets, circuits, bases, rank, closure, geometric representations of matroids, transversal matroids, the lattice of atoms, the greedy algorithm, duality of matroids, minors, and connectivity. The course provides a deep understanding of matroid theory and its applications in various areas of mathematics and computer science.

Course Objectives:

- To introduce the basic definitions and examples of matroids and their connection to linear independence and spanning trees.
- To understand and analyze independent sets, circuits, bases, rank in matroids, closure operation in matroids and its relationship to the concept of spanning sets.
- To explore geometric representations of matroids of small rank and their applications.
- To introduce transversal matroids and their properties.
- To analyze the greedy algorithm and its application in solving optimization problems related to matroids.
- To study the concept of duality in matroids and its basic properties.
- To understand the concept of minors in matroids, including contraction and minors of certain matroids.
- To analyze the properties of connectivity in matroids, both for graphs and matroids.

Course Contents:

1) **Introduction:** Basic definitions and examples, Independent sets and circuits, bases, rank, closure, geometric representations of matroids of small rank, transversal matroids, the lattice of atoms, the greedy algorithm.
2) **Duality:** The definition and basic properties, duals of representable matroids, duals of graphic matroids, duals of traversal matroids.
3) **Minors:** Contraction, Minors of certain matroids, atoms and the sum theorem
4) **Connectivity:** Connectivity, for graphs and matroids, properties of matroid connectivity, more properties of connectivity.

Reference Books:

- James G. Oxley, Matroid Theory Science Publications, Oxford, 1992.

MTE-11: Statistics and Probability

Course Description:

The course "Statistics and Probability" provides an introduction to statistical analysis and probability theory. It covers various topics including descriptive statistics, probability concepts, random variables, discrete and continuous probability distributions, functions of random variables, hypothesis testing, and practical applications using statistical software.

Course Objectives:

- To understand the fundamentals of descriptive statistics and data analysis techniques.
- To introduce the concept of probability and its applications in real-world scenarios.
- To explore different types of random variables and their distributions.
- To understand the properties of discrete and continuous probability distributions.
- To study the concepts of moments and moment-generating functions.
- To learn hypothesis testing techniques and their applications in statistical inference.
- To gain practical skills in statistical analysis using the R software.

Course Contents:

1) **Descriptive Statistics:** Measure of central tendency, Measure of dispersion, Graphical representations of data and its interpretation, Exploratory data analysis, correlation, covariance.
2) **Introduction to Probability:** Intuitive concepts: Sample space, events, probability of an event, additive rules, conditional probability, multiplicative rule, Bayes' rule.
3) **Random Variable:** Concept of a random variable, discrete probability distribution, continuous probability distribution, joint probability distribution, independent random variables, Chebyshev's theorem. Mean of a random variable, variance and covariance, mean and covariance of linear combinations of random variables.
4) **Some Discrete Probability Distributions:** discrete uniform distribution, binomial and multinomial distributions, hypergeometric distribution, negative binomial and geometric distribution, Poisson distribution and Poisson process.
5) **Some Continuous Probability Distributions:** continuous uniform distribution, normal distribution, area under the normal curve, applications of the normal distribution, normal approximation to the binomial distribution, gamma and exponential distribution, chi-squared distribution, lognormal distribution, Weibull distribution.
6) **Functions of random variables**, transformations of variables, moments and moment generating functions.
7) **Hypothesis Testing:** Statistical Hypothesis, general concepts, testing a statistical hypothesis, types of errors in testing of hypothesis, level of significance, critical regions, use of p values for decision making, tests of significance for single mean (variance known), tests of significance for single mean (variance unknown), confidence interval estimation.
8) **Practicals** on the all topics in course using R software.

Reference Books:

- R. Walpole, R.H. Myers, S.L. Myers, and K. Ye, Probability and Statistics for Engineers and Scientists, 7^{th} Edition, Pearson, India.
- Anderson, Sweeney and Williams, Statistics for Business and Economics.

- Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists, 4^{th} Edition.
- Parimal Mukhopadhyay, Mathematical Statistics.
- M. Samules, J. Witmer and A. Schaffner, Statistics for the Life Sciences, 5^{th} Edition, Pearson India
- Richard Gupta, C B Gupta, Probability and Statistics for Engineers.

MTE-12: Algebraic Number Theory

Course Description:
Algebraic Number Theory is a course that focuses on the study of algebraic numbers, number fields, rings of integers, integral bases, discriminants, norms, traces, quadratic and cyclotomic fields, factorization of ideals, norm of an ideal, non-unique factorization of ideals, geometric methods in algebraic number theory, lattices, quotient torus, Minkowski's theorem, the Two Squares Theorem, the Four Squares Theorem, geometric representation of algebraic numbers, class-group and class number, and computational methods in algebraic number theory. The course provides a deep understanding of the algebraic, geometric, and computational aspects of number theory.

Course Objectives:
- To introduce the algebraic methods used in algebraic number theory, including algebraic numbers, number fields, and rings of integers.
- To understand integral bases and discriminants of number fields.
- To explore norms and traces of elements in number fields.
- To study rings of algebraic integers, focusing on quadratic and cyclotomic fields.
- To analyze the factorization of elements and ideals into irreducible elements in number fields.
- To introduce geometric methods in algebraic number theory, including lattices, quotient torus, and Minkowski's theorem.
- To study classical theorems in number theory, such as the Two Squares Theorem and the Four Squares Theorem.
- To introduce computational methods in algebraic number theory, focusing on factorization of rational primes and class number calculations.

Course Contents:
1) **Algebraic Methods:** Algebraic numbers and integers, Number fields and ring of integers, Integral basis and discriminant, norms and traces, Rings of algebraic integers, Quadratic and Cyclotomic fields, factorization into irreducibles, Prime factorization of ideals, norm of an ideal, non-unique factorization of ideals
2) **Geometric Methods:** Lattices and quotient torus, Minkowskis theorem, Two Squares Theorem, Four Squares Theorem, Geometric representation of algebraic numbers, Class-group and Class number, finiteness of Class group
3) **Computational Methods:** Factorization of a Rational prime, some class number calculations

Reference Books:

- Ian Stewart and David Tall, Algebraic Number Theory and Fermats Last Theorem, 3^{rd} Edition A K Peters Ltd.
- Jurgen Neukirch, Algebraic Number Theory, Springer.

MTE-13: Integral Equations and Transforms

Course Description:

This course is a study of concept of different types of linear and nonlinear integral equations such as Fredholm integral equations, Volterra integral equations, and Abel's integral equation using some methods such as direct computation method, series solution method, and decomposition method. Moreover, this course also aims to study different types of integral transforms such as Laplace transforms and Fourier transforms.

Course Objectives:

On completion of the course, student will be able to:

- Classify different types of integral equations.
- Study different methods for solving integral equations.
- Study different type of integral transforms
- Solve particular examples and exercises of integral equations Applications

Course Contents:

1) **Classification of Liner Integral Equations:** Fredholm Volterra Integro-Differential Equations, Singular Integral Equations, Converting Volterra Equation to ODE, Conversion of IVP to Volterra equation Conversion of BVP to Fredholm equation.
2) **Fredholm Integral Equations:** Decomposition method, Direct Computation method, successive approximation method, method of successive substitutions, Homogeneous Fred- holm Equations, Comparison between alternative methods.
3) **Volterra Integral Equation:** Adomian Decomposition method, Series solution method, converting Volterra equation to VIP, Successive Approximation method, successive substitution method, comparison between alternative methods.
4) **Integro-Differential Equations:** Introduction, Direct Computation method, Adomian Decomposition Method. Conversion to Fredholm integral Equation. Volterra Integro-Differential equations Series Solution, Decomposition Method, Conversion to IVP.
5) **Singular Integral Equations:** Abel problem, Generalized Abel Integral Equation, Weakly- singular Volterra Equations.
6) **Non-Linear Integral Equations:** Nonlinear Fredholm Integral equations, Direct Computation, decomposition method, Non-linear Volterra Integral Equation, Series solution, De- composition method. Existence and uniqueness of solutions using fixed-point theorems in the case of Linear and nonlinear Volterra and Fredholm integral equations.
7) **Fourier Transforms [FT]:** Definition Properties evaluation of Fourier and inverse Fourier transforms of functions, Convolution theorem for FT. Sine and Cosine Fourier transforms. Solving differential equations and integral equations using FT.
8) **Laplace Transform:** Definition Properties, evaluation of Laplace and Inverse Laplace transforms of functions. Convolution theorem for Laplace Transforms. Solving initial value problem using Laplace Transforms. Solving integral equation using Laplace Transforms.

Reference Books:

- A.M. Wazwaz, A First course in integral equations, World Scientific,1997.
- A.J. Jerri, Introduction to Integral Equation with Applications, 2nd edition, Wiley Interscience, 1999.

MTE-14: Field Theory

Course Description:

Field Theory is a course that focuses on the study of field extensions, Galois theory, and their applications. The course covers topics such as basic theory of field extensions, algebraic extensions, classical straightedge and compass constructions, splitting fields, algebraic closures, separable and inseparable extensions, cyclotomic polynomials, Galois theory, normal extensions, the Fundamental Theorem of Galois Theory, finite fields, composite and simple extensions, symmetric polynomials, the Fundamental Theorem on Symmetric Polynomials, Galois groups of polynomials, solvable and radical extensions, and the insolvability of the quintic equation. The course provides a deep understanding of field theory and its applications in algebra and other areas of mathematics.

Course Objectives:

- To introduce the basic theory of field extensions and their properties. Further, to understand algebraic extensions and their relationship with roots of polynomials.
- To study classical straightedge and compass constructions and their connection to field extensions, splitting fields and algebraic closures and their role in finding all the roots of a polynomial.
- To analyze cyclotomic polynomials and their connection to field extensions.
- To introduce Galois theory, its basic definitions and normal extensions and their properties, Fundamental Theorem of Galois Theory and its implications.
- To explore finite fields and their properties.
- To understand the Fundamental Theorem on Symmetric Polynomials and its applications, Galois groups of polynomials and their properties.
- To introduce solvable and radical extensions and their connection to Galois theory.
- To study the insolvability of the quintic equation and its proof using Galois theory.

Course Contents:

1) **Field Extensions:** Basic theory of field extensions, algebraic extensions, classical straightedge and compass Constructions, splitting fields and algebraic closures, Separable and Inseparable Extensions, cyclotomic polynomials and extensions
2) **Galois Theory:** Basic definitions, normal extensions, The Fundamental Theorem of Galois Theory, finite fields, composite and simple extensions, symmetric polynomials, Fundamental theorem on Symmetric Polynomials, Galois groups of polynomials, solvable and radical extensions, insolvability of the quintic.

Reference Books:

- Joseph Rotman, Galois Theory, 2nd Edition, Springer.
- Dummit and Foote, Abstract Algebra, 2nd Edition, Wiley Eastern Ltd.
- P. Bhattacharya and S. Jain, Basic Abstract Algebra, Second Edition,Cambridge University Press.

MTE-15: Coding Theory

Course Description:

Coding Theory is a course that focuses on the study of error detection, error correction, and decoding in communication channels. The course covers topics such as maximum likelihood decoding, Hamming distance, nearest neighbor/minimum distance decoding, linear codes, vector spaces over finite fields, Hamming weight, bases of linear codes, generator matrix and parity check matrix, equivalence of linear codes, encoding with a linear code, decoding of linear codes, cossets, syndrome decoding, cyclic codes, generator polynomials, generator and parity check matrices, decoding of cyclic codes, burst-error-correcting codes, BCH codes, and parameters of BCH codes. The course provides a solid foundation in coding theory and its applications in error detection and correction in various communication systems.

Course Objectives:

- To introduce the concepts of error detection, error correction, and decoding in communication channels.
- To study the concept of Hamming distance and its role in error detection and correction, explore nearest neighbor/minimum distance decoding and its application in error correction. Further, to understand linear codes as vector spaces over finite fields, Hamming weight and its significance in linear codes.
- To study bases of linear codes, including generator matrix and parity check matrix representations.
- To explore encoding with a linear code and the process of transmitting information using linear codes. Further, to study the decoding techniques for linear codes, including cossets and nearest neighbor decoding.
- To understand syndrome decoding and its application in error correction for linear codes.
- To introduce cyclic codes and their properties, including generator polynomials and generator/parity check matrices.
- To study the decoding process for cyclic codes and their application in burst-error correction.
- To explore special cyclic codes, specifically BCH codes, and their parameters.

Course Contents:

1) **Error detection:** correction and decoding: Communication channels, Maximum likelihood decoding, Hamming distance, Nearest neighbour / minimum distance decoding, Distance of a code.
2) **Linear codes:** Vector spaces over finite fields, Linear codes, Hamming weight, Bases of linear codes, Generator matrix and parity check matrix, Equivalence of linear codes, encoding with a linear code, Decoding of linear codes, Cossets, Nearest neighbour decoding for linear codes, Syndrome decoding.
3) **Cyclic codes:** Definitions, Generator polynomials, Generator and parity check matrices, decoding of cyclic codes, Burst-error-correcting codes.
4) **Some special cyclic codes:** BCH codes, Definitions, Parameters of BCH codes

Reference Books:

- San Ling and Chaoing xing, Coding Theory- A First Course
- Raymod Hill, A First Course in Coding Theory, Oxford.
- Lid and Pilz, Applied Abstract Algebra, 2nd Edition

MTE-16: Financial Mathematics

Course Description:

Financial Mathematics is a course that focuses on the study of options and markets, option valuation models, and various numerical methods used in financial mathematics. The course covers topics such as the introduction to options and markets, Black-Scholes model, option values, payoffs and strategies, put-call parity, the Black-Scholes equation, exact formulas for European options, American options, binomial methods, Monte Carlo simulation, finite difference methods, and a lab component involving the implementation of option pricing algorithms and evaluations for Indian companies. The course provides a comprehensive understanding of option pricing and the application of numerical methods in financial mathematics.

Course Objectives:

- To introduce the types of options and their role in financial markets.
- To study the Black-Scholes model and its application in option valuation.
- To analyze option values, payoffs, strategies in different market scenarios, put-call parity and its significance in option pricing.
- To understand the Black-Scholes equation and its solution for European options, American options and the free boundary problem associated with them.
- To analyze option valuation using binomial methods, considering dividend-paying stocks and general formulations.
- To explore option valuation through Monte Carlo simulation.
- To study finite difference methods, including explicit and implicit methods, for option valuation.

Course Contents:

1) **Introduction to options and markets:** types of options, interest rates and present values.
2) **Black Sholes model:** arbitrage, option values, pay o_s and strategies, put call parity, Black Scholes equation, similarity solution and exact formulae for European options, American option, call and put options, free boundary problem.
3) **Binomial methods:** option valuation, dividend paying stock, general formulation and implementation.
4) **Monte Carlo simulation:** valuation by simulation
5) **Finite difference methods:** explicit and implicit methods with stability and conversions analysis methods for American options- constrained matrix problem, projected SOR, time stepping algorithms with convergence and numerical examples.
6) **Lab component:** implementation of the option pricing algorithms and evaluations for Indian companies.

Reference Books:

- D. G. Luenberger, Investment Science, Oxford University Press,1998.
- J. C. Hull , Options, Futures and Other Derivatives, 4th Edition, Prentice- Hall ,New York, 2000.
- J. C. Cox and M. Rubinstein, Option Market, Prentice- Hall, 1985.
- C.P. Jones. Investments, Analysis and Measurement, 5th Edition.,John Wiley and Sons, 1996.

MTE-17: Algebraic Topology

Course Description:

Algebraic Topology is a course that focuses on the study of algebraic invariants associated with topological spaces. The course covers topics such as quotient spaces, homotopy of paths, fundamental group, covering spaces, retraction and fixed points, algebraic topological proof of the Fundamental Theorem of Algebra, Borsuk-Ulam theorem, deformation retracts and homotopy type, fundamental group of Sn (the n-dimensional sphere), Seifert-van Kampen theorems, free groups, fundamental group of a wedge of circles, fundamental group of a torus and dunce cap, and optionally, the group of covering transformations. The course provides a deep understanding of the algebraic invariants and techniques used in studying the properties of topological spaces.

Course Objectives:

- To introduce quotient spaces and their properties in algebraic topology.
- To understand the concept of homotopy of paths and its significance in topology, fundamental group, a fundamental algebraic invariant associated with topological spaces.
- To explore covering spaces and their relationship with the fundamental group, fixed points, and their properties in topological spaces.
- To understand the algebraic topological proof of the Fundamental Theorem of Algebra.
- To study the Borsuk-Ulam theorem, which relates to continuous functions on spheres.
- To understand the fundamental group of Sn, the n-dimensional sphere.
- To study the Seifert-van Kampen theorems, which provide a method for calculating the fundamental group of complicated spaces.
- To introduce free groups and their role in algebraic topology.

Course Contents:

Quotient spaces, examples and properties of quotient spaces, homotopy of paths, fundamental group, covering spaces, retraction and fixed points, Algebraic topological proof of Fundamental Theorem of Algebra, Borsuk-Ulam theorem, deformation retracts and homotopy type, fundamental group of Sn, Seifert-van Kampen theorems, free groups, fundamental group of wedge of circles, fundamental group of torus and dunce cap,
group of covering transformations(optional).

Reference Books:

- James Munkres , 2nd Edition, Topology, Pearson Publications.
- Allen Hatcher, Algebraic Topology

MTE-18: Cryptography

Course Description:

Cryptography is a course that focuses on the study of cryptographic techniques and systems. The course covers topics such as divisibility and the Euclidean algorithm, congruences, factorizations, finite fields, quadratic residues, simple cryptosystems, integer factorization, discrete logarithm, public key cryptography, hash functions, RSA (Rivest-Shamir-Adleman), Diffie-Hellman key exchange system, the ElGamal cryptosystem, digital signatures, primality and factoring, primality tests, pseudo primes, Miller-Rabin primality test, elliptic curve cryptography, and elliptic curve cryptosystems. The course provides a comprehensive understanding of the mathematical foundations of cryptography and various cryptographic algorithms.

Course Objectives:

- To introduce the concept of divisibility and the Euclidean algorithm,
- congruences and their applications in cryptographic algorithms.
- To study factorizations of numbers and their relevance to cryptographic systems. Further, to explore finite fields and quadratic residues in the context of cryptography.
- To study integer factorization and the challenges associated with breaking cryptographic systems.
- To understand the discrete logarithm problem and its significance in cryptography.
- To analyze the RSA algorithm, which is widely used in public key cryptography.
- To understand the Diffie-Hellman key exchange system and its role in secure communication.
- To explore the ElGamal cryptosystem and its mathematical foundations.
- To study digital signatures and their applications in verifying the authenticity of digital documents.
- To understand primality and factoring of numbers and their relevance to cryptography.
- To explore primality tests, including pseudo primes and the Miller-Rabin primality test.

Course Contents:

Divisibility and Euclidean Algorithm, Congruences, Factorizations, finite fields and quadratic residues, some simple cryptosystems, integer factorization, discrete logarithm, public key cryptography, hash functions, RSA, Diffie Hellman key exchange system, the ElGamal cryptosystem, digital signatures, primality and factoring, primality tests, pseudo primes, Miller-Rabin primality test, elliptic curve cryptography, elliptic curve cryptosystems.

Reference Books:

- Neal Koblitz, A Course in Number Theory and Cryptography, 2nd Edition, Springer.
- Robert Edward Lewand: Cryptological Mathematics (Mathematical Association of America).
- D. R. Stinson: CRYPTOGRAPHY, Theory and practice, CRC Press, 1995
- Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman: An introduction to Mathematical Cryptography, Springer
- Adam J. Elbirt: (CRC press): Understanding and Applying cryptography and Data security.

- Bruice Schneier: Applied Cryptography, Wiley India Edition.
- Atul Kahate: Cryptography and Network security, Tata McGraw Hill.

MTE 19: Differential Geometry

Course Description:

Differential Geometry is an advanced course that explores the mathematical study of curves and surfaces in multidimensional spaces. This course provides a rigorous introduction to the fundamental concepts and techniques of differential geometry, focusing on the geometry of curves and surfaces. It covers topics such as vector fields, tangent spaces, orientation, curvature, geodesics, and surface area. Additionally, it introduces important tools and methods for understanding the intrinsic geometry of curves and surfaces, including the Gauss map, Weingarten map, and exponential map. Applications of differential geometry to various fields, such as physics and computer graphics, will also be discussed.

Course Objectives:

- Understand the basic concepts and principles of differential geometry, specifically in the context of curves and surfaces.
- Develop proficiency in working with vector fields and tangent spaces, and their applications in differential geometry.
- Analyze the geometry of surfaces, including properties such as orientation, curvature, and surface area.
- Study the behavior of curves on surfaces, including geodesics and parallel transport.
- Explore the Gauss map and its role in understanding the local and global properties of surfaces, Weingarten map and its relationship to curvature, providing insights into the shape of surfaces.
- Apply the concepts of differential geometry to calculate arc length, line integrals, surface area, and volume of parametrized surfaces.
- Utilize the exponential map to understand the behavior of curves and surfaces in relation to their local geometry.
- Examine surfaces with boundaries and explore their unique geometric properties.

Course Contents:

Graphs and level sets, vector fields, tangent spaces, surfaces, vector fields on surfaces, orientation, gauss map, geodesics, parallel transport, Weingarten map, curvature, arc length and line integrals, curvature of surfaces, parametrized surfaces, surface area and volume, exponential map, surfaces with boundary.

Reference Books:

- John A. Thorpe, Elementary topics in differential Geometry, Springer, 2004.
- B Oneill : Elementary differential Geometry, Academic - New York.

MTE-20: Introduction to Data Science

Course Description:

Introduction to Data Science is a comprehensive course that introduces students to the fundamental concepts, techniques, and tools used in the field of data science. The course explores the role of data science in the era of big data and provides a strong foundation in statistical analysis and predictive modeling. Students will gain hands-on experience through lab sessions using Python programming and learn how to effectively preprocess and analyze data, build predictive models, and evaluate their performance. By the end of the course, students will have a solid understanding of the key principles of data science and be able to apply them to real-world scenarios.

Course Objectives:

- Understand the need, benefits, and applications of data science in the context of big data.
- Recognize the importance of mathematics and statistics as foundational disciplines for data science.
- Develop skills in data preprocessing, including handling missing values, data wrangling, and data visualization.
- Learn various supervised and unsupervised machine learning techniques for predictive modeling.
- Gain proficiency in evaluating and selecting appropriate evaluation metrics for machine learning models.
- Apply the concepts and techniques learned in the course to practical scenarios through lab sessions.

Course Contents:

1) **Data Science in a big data world:** Need, benefits and uses of data science and big data, Overview of the data science process, The big data ecosystem and data science, Challenges in big data world, Importance of Mathematics and Statistics in data science
2) **Statistical Foundation for Data Science:** Data and data representation Techniques, Measure of Central Tendency and Variability, Exploratory Data Analysis, Introduction to probability and probability distributions, Methods of Estimation, Testing of Hypothesis, Analysis of Variance
3) **Data Pre-processing:** Data and data quality, Missing Value Analysis and Data wrangling, Label encoding and feature selection, Data Visualization techniques, Data integration and reshaping, Graph mining methods, Tex mining techniques
4) **Predictive Modelling:** Supervised Learning, Regression Analysis: Linear, Non-linear and correlation, Time Series Analysis: ARIMA, SARIMA, VERMAX, Classification Techniques: Logistic regression, Decision trees, Random forest, Support Vector Machine, Unsupervised

Learning, Clustering: K-means, Hierarchical clustering, density-based clustering, Dimensionality reduction using PCA and t-SNE, Association rules mining, Evaluation metrics for Machine Learning models

5) **Lab sessions on different statistical and machine learning techniques covered in course.**
6) **Pre-requisite:** Programming in Python

Reference Books:

- Foster Provost and Tom Fawcett, Data Science for Business, O'REILLY publications, 2013.
- Joel Grus, Data Science from Scratch, O'REILLY publications, 2015.
- Peter Bruce, Andrew Bruce & Peter Gedeck, Practical Statistics for Data Scientists, 2^{nd} Edition.
- Davy Cielen, Amo D. B. Meysman, Mohamed Ali, Introducing Data Science, Manning Publications Co., 1^{st} Edition, 2016.
- Jiawei Han, Micheline Kamber & Jian Pei, Data Mining, Concepts and Techniques, 3^{rd} Edition.
- Ethem Alpaydin, Introduction to Machine Learning, 2^{nd} Edition, The MIT Press.
- S. C. Gupta, Fundamentals of Statistics, Himalaya Publishing House

<u>MTE-21: Mechanics</u>

Course Description:

The course "Mechanics" focuses on the study of classical mechanics, including Lagrangian and Hamiltonian formulations, calculus of variations, and the motion of rigid bodies. The course covers topics such as Lagrange's formulation, calculus of variation, Hamilton's formulation, the central force problem, and kinematics of rigid body motion.

Course Objectives:

- To understand the principles and mathematical techniques used in classical mechanics.
- To learn Lagrange's formulation and its application in analyzing the motion of particles and systems of particles.
- To study the calculus of variations and its role in deriving Euler's equations for functionals involving single and multiple dependent variables.
- To explore Hamilton's formulation and its connection to Lagrangian mechanics, canonical equations of motion, and the principle of least action.
- To analyze the motion of particles under central forces and understand the Kepler's laws of planetary motion.
- To study the kinematics of rigid body motion, including orthogonal transformations, Eulerian angles, moments of inertia, and Euler's equations of motion for a rigid body.

Course Contents:

1) **Lagrange's formulation:** Mechanics of a particle and system of particles, Constraints, degrees of freedom and generalized coordinates, Conservative and non-conservative forces. D'Alembert's principle and Lagrange's equations of motion. Kinetic energy as a homogeneous quadratic function of generalized velocities. Conservation theorems. Simple applications of the Lagrangian formulation. Cyclic coordinates and conservation theorems.
2) **Calculus of Variation:** Basic lemma, Euler's equations for a functional involving a single dependent variable; several dependent variables and for a functional involving higher order derivatives. A case of variable end points. Geodesics in two and three dimensional Euclidean space, Geodesics on different surfaces, Minimum surface of revolution, the Brachistochrone problem. Isoperimetric problems for a functional of a single dependent variable; several dependent variables and involving higher derivatives. Simple applications.
3) **Hamilton's Formulation:** Hamilton's principles and its derivation from D'Alembert's principle for conservative and non- conservative systems. Simple applications of Hamilton's principle. Hamiltonian function. Hamilton's canonical equations of motion. Hamilton's equations of motion for

the partially conservative and partially non-conservative systems. Derivation of Lagrange's equations of motion and Hamilton's canonical equations of motion from Hamilton's principles. Physical meaning of the Hamiltonian. Routh's procedure. The principle of least action. Simple applications of Hamilton's formulation.

4) **Central Force problem:** Central force, areal velocity, Perihelion and Aphelion, Two body problem. Lagrangian for two bodies moving under central force. Lagrange's equation of motion and its first integral. The Kepler's laws of planetary motion. Differential equation of the orbit of a planet. Virial theorem. Simple applications of central force motion.

5) **Kinematics of rigid body motion:** Rigid body and its generalized coordinates, motion of a rigid body. Orthogonal transformation. Some properties of orthogonal transformation matrix. Eulerian angles, matrix of transformation in Eulerian angles. Moments of inertia and products of inertia. Kinetic energy of a rigid body with one point fixed. Euler's equations of motion of a rigid body with one point fixed. Cayley-Klein parameters. Matrix of transformation in terms of Cayley-Klein parameters. Relation between Cayley-Klein parameters and Eulerian angles.

Reference Books:

- Herbert Goldstein: Classical Mechanics, Narosa Publishing House, 1993.
- S. Gupta: Calculus of Variation with Application, Prentice-Hall of India Private Limited, 2005.
- I. M. Gelfand and S. V. Fomin: Calculus of varitions, Prentice-Hall Inc. 1963.
- L. N. Katkar: Problems in Classical Mechanics, Alpha Science International Ltd, 2014.

MTE-22: Advanced Calculus II

Course Description:
Advanced Calculus II is a course that focuses on advanced topics in calculus, specifically multilinear algebra, differential forms, vector fields, integrating forms, and manifolds. The course covers topics such as multilinear algebra, including alternating tensors and the wedge product, tangent vectors and differential forms, the differential operator, vector fields, integrating forms, orientable manifolds, Stokes' theorem, closed and exact forms, Poincaré's lemma, and manifolds in the abstract setting. The course provides a deep understanding of these advanced concepts and their applications in mathematical analysis and geometry.

Course Objectives:
- To introduce multilinear algebra and its applications in calculus and geometry, alternating tensors and their significance in multilinear algebra, the wedge product, and its properties and differential forms.
- To analyze tangent vectors and differential forms and their relationship with calculus and differential geometry.
- To study integrating forms and their role in the integration of differential forms over manifolds, orientable manifolds and their properties in the context of differential forms.
- To study Stokes' theorem and its applications in the integration of differential forms over manifolds.
- To understand closed and exact forms and their significance in differential forms and calculus.
- To explore Poincaré's lemma and its implications for closed and exact forms.

Course Contents:
Multilinear Algebra, alternating tensors, wedge product, tangent vectors and differential forms, differential operator, Vector fields, Integrating forms, orientable manifolds, Stokes theorem, Closed and exact forms, Poincare's lemma, manifolds in the abstract Setting (abstract manifolds).

Reference Books:

- J. R. Munkers, Analysis on Manifolds , Addison Wesley, 1993.
- Michael Spivak, Calculus on Manifolds, Addison-Wesley Publishing Co.

MTE-23: Advanced Linear Algebra

Course Description:
Advanced Linear Algebra is a course that focuses on advanced topics in linear algebra, including normal, unitary, and self-adjoint operators, spectral theorem for normal operators, quadratic forms, orthogonal reduction, discrete Fourier transform (DFT), orthogonal decomposition, singular value decomposition, orthogonal projections, least squares solutions, Perron-Frobenius theory, stochastic matrices, and applications to Markov chains. The course also covers modules over principal ideal domains (PIDs), including modules over PIDs, Smith normal form, elementary divisors, invariant factors, and Jordan and/or rational canonical forms via modules over PIDs. The course provides a deep understanding of these advanced concepts and their applications in linear algebra and related areas.

Course Objectives:

- To introduce the concepts of normal, unitary, and self-adjoint operators and their properties in linear algebra.
- To study the spectral theorem for normal operators and its implications.
- To analyze quadratic forms and their properties in linear algebra.
- To explore orthogonal reduction techniques and their applications in matrix computations.
- To understand the discrete Fourier transform (DFT) and its applications in signal processing and data analysis.
- To analyze the singular value decomposition (SVD) and its applications in data analysis and image processing.
- To understand the concept of least squares solutions and their significance in linear regression and optimization problems.
- To study Perron-Frobenius theory and its applications in the analysis of positive matrices and Markov chains.
- To introduce modules over principal ideal domains (PIDs) and their properties, Smith normal form and its applications in module theory and linear algebra.
- To analyze elementary divisors and invariant factors of modules over PIDs. Further, to explore Jordan and/or rational canonical forms and their connection to modules over PIDs.

Course Contents:

1) Normal, unitary and self-adjoint operators, spectral theorem for normal operators, quadratic forms, orthogonal reduction, Discrete Fourier Transform (DFT), orthogonal decomposition, singular value decomposition, orthogonal projections, least squares solutions, Perron-Frobenius theory, stochastic matrices and applications to Markov chains.
2) Modules over PID: Modules over PIDs, smith normal form, elementary divisors, invariant factors, Jordan and / or Rational canonical forms via modules over PIDs.

Reference Books:

- K. Hoffman and R. Kunze, Linear Algebra, 2^{nd} Edition, Prentice Hall.
- C. D. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2001.
- Steven Roman, Advanced Linear Algebra.
- Peter Lax, Linear Algebra.

MTE-24: Banach Algebra

Course Description:

Banach Algebra is a course that focuses on the study of Banach algebras, including compact operators, spectra, resolvent sets, approximate eigenvalues, Banach algebras with identity, the Gelfand theory, sesquilinear functions, the Fredholm alternative theory, the spectral theorem for bounded normal finite-dimensional operators, commutative Banach algebras, ideals, and homomorphisms. The course provides a deep understanding of these advanced topics in functional analysis and their applications in various areas of mathematics.

Course Objectives:

- To introduce the concept of relatively compact sets and their properties in Banach spaces, compactly continuous operators and their role in compactness of operators.
- To explore finite-dimensional operators and their properties, completely continuous transformations and their properties.
- To understand spectra and the resolvent set of operators in Banach algebras.
- To analyze approximate eigenvalues and their significance in spectral theory.
- To understand the spectral radius and the spectral mapping theorem for polynomials, the Gelfand theory and its implications for Banach algebras.
- To study sesquilinear functions and their spectral results for normal and completely continuous operators.
- To understand the Fredholm alternative theory and its applications in operator equations, spectral theorem for bounded normal finite-dimensional operators.
- To study commutative Banach algebras and their properties, ideals and homomorphisms in Banach algebras.

Course Contents:

1) Relatively compact sets, compactly continuous operators, finite dimensional operators, ransformation that is bounded but not completely continuous, a type of transformation that is always completely continuous, further properties of completely continuous transformations.
2) Spectra and the resolvent set, Approximate proper values, Banach Algebra with identity, compactness of the spectrum, the resolvent operator, Spectral radius and spectral mapping theorem for polynomials, the Gelfand Theory.

3) Sesquilinear functions: Spectral results for normal and completely continuous operators, numerical range
4) The Fredholm alternative theory, the spectral theorem for bounded, normal Finite dimensional operators.
5) Commutative Banach Algebras, ideals and homomorphisms.

Reference Books:

- Walter Rudin, Functional Analysis, Tata Mac Grow Hill Publishing co. New Delhi.

MTE-25: Logic and Set Theory

Course Description:

The Logic and Set Theory course is designed to provide postgraduate students with a comprehensive understanding of the foundations of mathematical logic and set theory. The course covers topics such as propositional and predicate logic, formal proof systems, set operations, relations, functions, and cardinalities. Emphasis is placed on developing students' ability to analyze logical arguments, construct rigorous proofs, and apply set-theoretic concepts in various mathematical disciplines.

Course Objectives:

- To introduce students to the fundamentals of mathematical logic and its applications in mathematics.
- To develop skills in constructing and analyzing logical arguments using propositional and predicate logic.
- To provide a deep understanding of set theory, including set operations, relations, functions, and cardinalities.
- To enhance students' ability to construct formal proofs and reason mathematically.
- To foster critical thinking and problem-solving skills through the application of logic and set theory concepts.

Course Contents:

1) **Introduction to Mathematical Logic:** Propositional logic: syntax, semantics, and truth tables, Predicate logic: quantifiers, logical connectives, and inference rules, Formal proof systems: natural deduction and axiomatic systems.
2) **Logical Reasoning and Proof Techniques:** Deductive reasoning and logical equivalences, Proof strategies: direct proof, proof by contradiction, and proof by induction, Mathematical induction, and recursive definitions.
3) **Set Theory Foundations:** Sets and their representations, Operations on sets: union, intersection, complement, and power set, Relations and functions: equivalence relations, partial orders, and bijections.
4) **Axiomatic Set Theory:** Zermelo-Fraenkel (ZF) axioms and the Axiom of Choice (AC), Cardinal and ordinal numbers, Transfinite induction, and recursion.
5) **Infinite Sets and Cardinalities:** Countable and uncountable sets, Cantor's diagonal argument, the continuum hypothesis Cardinal arithmetic, and the Schröder-Bernstein theorem.

6) **Applications of Logic and Set Theory:** Mathematical structures: groups, rings, and lattices, First Order Theories, Model theory and formal languages, Gödel's incompleteness theorems and their implications.

Reference Books:

- "Set Theory and Logic" by Robert R. Stoll, Dover Publications, Inc. NewYork, 1963.
- "Set Theory" by Kenneth Kunen, Studies in Logic Mathematical Logic and Foundations Volume 34, College Publication, 2013.
- "Mathematical Logic" by Stephen Cole Kleene, Dover Publications, Inc. NewYork, 1967
- "Set Theory: An Introduction to Independence Proofs" by Kenneth Kunen, NORTH HOLLAND PUBLISHING COMPANY-1980
- "Naive Set Theory" by Paul R. Halmos, Dover Publications, Inc. NewYork, 2017.

Note: The provided syllabus and reference books are a general outline and can be adapted and expanded based on the specific requirements of the institution and the expertise of the faculty members teaching the course.

MTE-26: Quantum Computing

Course Description:
This course provides an introduction to the principles and applications of quantum computing. Students will learn the foundational concepts of quantum mechanics, explore quantum algorithms, and understand the potential of quantum technologies. The course covers topics such as quantum circuits, entanglement, quantum algorithms, quantum information, and quantum cryptography. Students will gain practical knowledge of quantum computing through theoretical discussions and hands-on exercises.

Course Objectives:
- To introduce students to the fundamental principles and concepts of quantum computing.
- To develop an understanding of the circuit model of quantum computation.
- To explore quantum algorithms and their applications.
- To equip students with the knowledge and skills to apply quantum algorithms to real-world problems.
- To familiarize students with quantum information theory and quantum cryptography.
- Course Contents:

Course Contents:
1) **Introduction to Quantum Computing:** Quantum Mechanics, Church-Turing Thesis, The Circuit Model of Computation, Linear Algebra Formulation of the Circuit Model, Reversible Computation,
2) **Quantum Computation:** Fundamentals of Quantumness, No-Cloning Theorem, Quantum Entanglement, Bell States and Bell Inequalities, Quantum Circuits, Pauli, Hadamard, Phase, CNOT, Toffoli Gates, Quantum Teleportation, Universality of Two-Qubit Gates, Reversible Computing,
3) **Quantum Algorithms:** Probabilistic Versus Quantum Algorithms, Phase Kickback, The Deutsch Algorithm, The Deutsch-Jozsa Algorithm, Simon's Algorithm, Quantum Phase Estimation and Quantum Fourier Transform, Grover's Quantum Search Algorithm, Shor's Period Finding Algorithm.
4) **Quantum Information:** Quantum Error Correction, Shannon Entropy, Von Neumann Entropy, Classical Cryptography, RSA Algorithm, Quantum Cryptography, BB84 Protocol, B92 and Eckart

Protocol.

Reference Books:

- Phillip Kaye, Raymond Laflamme, and Michele Mosca, An Introduction to Quantum Computing, Oxford University Press, 2007.
- Michael A. Nielsen, and Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2000.
- David McMahon, Quantum Computing Explained, John Wiley & Sons, Inc., 2008.
- Mermin N. David, Quantum Computer Science: An Introduction, Cambridge University Press, 2007.

MTE-27: Statistical Inference

Course Description:

Statistical Inference is a course that focuses on statistical methods for making inferences and drawing conclusions from data. The course covers topics such as correlation and regression analysis, chi-square distribution and tests, small sample tests using t distribution and F distribution, likelihood ratio tests, non-parametric tests, and analysis of variance (ANOVA). The course provides a comprehensive understanding of these statistical techniques and their applications in data analysis and hypothesis testing.

Course Objectives:

- To introduce correlation and regression analysis and their applications in analyzing the relationship between variables.
- To study Karl Pearson's coefficient of correlation and Spearman's rank correlation coefficient and their properties.
- To understand linear regression, lines of regression, and theorems on regression coefficients, statistical inferences about regression parameters and the estimation.
- To understand the chi-square distribution and its applications in goodness-of-fit tests and tests of independence.
- To analyze small sample tests using the t distribution, including confidence intervals, paired t-test, and tests for correlation coefficient.
- To study the Fisher's Z-transform and the F-distribution for tests of equality of variances, likelihood ratio tests and their applications in testing hypotheses about means, variances, and parameters of the binomial distribution.
- To introduce non-parametric tests and their advantages and limitations.
- To explore non-parametric tests such as the sign test, Wilcoxon signed rank test, and Mann-Whitney test, analysis of variance (ANOVA) including one-way and two-way ANOVA, the Kruskal-Wallis one-way analysis of variance by ranks and the Friedman two-way analysis of variance by ranks.

Course Contents:

1) **Correlation and Regression Analysis: -** Introduction and Scatter Diagrams , Karl Pearson’s Coefficient of Correlation, Properties and Problems ,Spearmen’s Rank correlation coefficient, method of Concurrent Deviations, interpretation of r and Probable Error, Linear Regression, Lines of Regression, Theorems on Regression Coefficients, Yule’s Rule, Order of Regression coefficients,

Statistical Inferences about the Regression Parameters, Variance of the Residual and the standard error of the estimate, Introduction to Multiple Correlation, Multiple linear Regression.

2) **Chi square distribution:** Introduction of Chi-square Distribution, Chi-square test for Goodness of Fit and its conditions for validity, Chi-Square test for independence of attributes, Degrees of Freedom, test for equality of several Proportions, Chi-square test for population variance, applications of Chi-square Distribution
3) **Small Sample Tests:** Critical Values and Applications of t distribution, Confidence Interval for a difference of two means, Paired t-test for the difference of two Means, t-test for significance of an observed sample correlation coefficient, Fisher's Z Transform, F distributions and its applications, F-test for equality of population variances, the relation between t, F and Chi-square Distributions.
4) **Likelihood Ratio Tests:** Notion of Likelihood Ratio Test (LRT), construction of LRT for mean of normal distribution (one and two-sided when variance is known/unknown), construction of LRT for variance of normal distribution (one and two sided when mean is known/unknown), LRT for parameters of Binomial distribution (two sided), LRT as a function-sufficient statistics, statement of Asymptotic Distribution of -2 log lambda(x)
5) **Non-Parametric Tests:** Introduction to Non-Parametric tests, Advantages and Limitations, Distribution Free Statistics, Sign Test, Wilcoxon Signed Rank Test, Mann Whitney Test,
6) **Analysis of Variance (ANNOVA):** One-Way Analysis of Variance, Two-Way Analysis of Variance, The Kruskal-Wallis One -Way analysis of variance by ranks, The Friedman Two-Way analysis of variance by ranks.

Reference Books:

- S. G. Gupta , Fundamentals of Statistics, Himalaya Publishing House.
- Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists, 4th Edition.
- Wayne W. Daniel, Biostatistics, A Foundation for Analysis in Health Sciences, by 8th Edition, Wiley Publications.
- Parimal Mukhopadhyay, Mathematical Statistics.
- M. Samuels, J. Witmer and A. Schaffner, Statistics for the Life Sciences, 5th Edition, Pearson India.
- Richard Gupta, C B Gupta, Probability and Statistics for Engineers.

MTE 28: Data Mining

Course Description:

Data Mining is a course that introduces the fundamental concepts, techniques, and applications of data mining. The course covers various topics such as data preprocessing, data warehousing, data mining techniques, including association rule mining and classification, accuracy measures, software for data mining, clustering, and an overview of advanced techniques in data mining. The course aims to give students the necessary knowledge and skills to analyze and extract valuable insights from large datasets.

Course Objectives:

- To introduce the concepts, tasks, and issues related to data mining.
- To understand the architecture of data warehousing and the use of OLAP, data cubes, and data preprocessing techniques, including data cleaning, integration, transformation, and reduction.
- To study data mining techniques such as frequent item-set, association rule and sequence mining.
- To understand classification and prediction techniques, including decision tree learning, Bayesian classification, and linear regression.
- To learn about accuracy measures for evaluating data mining models.
- To familiarize students with software tools used for data mining, such as R and Weka, and an overview of clustering techniques, including k-means, expectation-maximization, and hierarchical clustering.
- To introduce advanced topics in data mining such as active learning, reinforcement learning, text mining, graphical models, and web mining.

Course Contents:

1) **Introduction to Data Mining:** Basic Data Mining Tasks, DM versus Knowledge Discovery in databases, Data Mining Issues, Data Mining Metrics, Social Implications of Data Mining, Overview of Applications of Data Mining
2) **Introduction to Data warehousing:** Architecture of DW, OLAP and Data Cubes, Dimensional Data Modeling-star, snowflake schemas, Data Preprocessing Need, Data Cleaning, Data Integration & Transformation, Data Reduction, Machine Learning, Pattern Matching
3) **Data Mining Techniques:** Frequent item-sets and Association rule mining: Apriori algorithm, Use of sampling for frequent item-set, FP tree algorithm, Graph Mining: Frequent sub-graph mining, Tree mining, Sequence Mining
4) **Classification & Prediction:** Decision tree learning, Construction, performance, attribute selection Issues: Over-fitting, tree pruning methods, missing values, continuous classes, Classification and Regression Trees (CART), Bayesian Classification, Bayes Theorem, Nave Bayes classifier, Bayesian

Networks, Inference, Parameter and structure learning, Linear classifiers, Least squares, logistic, perceptron and SVM classifiers, Prediction, Linear regression, Non-linear regression.
5) **Accuracy Measures:** Precision, recall, F-measure, confusion matrix, cross-validation, bootstrap.
6) **Software for data mining and applications of data mining:** R, Weka, Sample applications of data mining.
7) **Clustering:** k-means, Expectation Maximization (EM) algorithm, Hierarchical clustering, Correlation clustering.
8) **Brief overview of advanced techniques:** Active learning, Reinforcement learning, Text mining, Graphical models, Web Mining.

References Books:

- Data Mining: Concepts and Techniques, Han, Elsevier
- Margaret H. Dunham, S. Sridhar, Data Mining Introductory and Advanced Topics, Pearson Education
- Tom Mitchell, Machine Learning, McGraw-Hill, 1997
- R.O. Duda, P.E. Hart, D.G. Stork. Pattern Classification. Second edition. John Wiley and Sons, 2000.
- Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer 2006
- Raghu Ramakrishnan, Johannes Gehrke, Database Management Systems, Second Edition, McGraw Hill International.
- Ian H. Witten, Eibe Frank Data Mining: Practical Machine Learning Tools and Techniques, Elsevier/(Morgan Kauffman),

MTE 29: Machine Learning

Course Description:

Machine Learning is a course that introduces the principles, algorithms, and techniques used in machine learning. The course covers various topics such as basic definitions in machine learning, types of learning, hypothesis space, evaluation methods, linear regression, decision trees, overfitting, instance-based learning, feature reduction, collaborative filtering, probability and Bayes learning, logistic regression, support vector machines, neural networks including perceptron and backpropagation, deep neural networks, and clustering techniques such as k-means and Gaussian mixture models. The course aims to provide students with a solid foundation in machine learning and its practical applications.

Course Objectives:

- To introduce the basic concepts and definitions in machine learning.
- To understand the different types of learning and the notion of hypothesis space and inductive bias, evaluation methods in machine learning, including cross-validation.
- To study linear regression and its applications in modeling relationships between variables, decision trees and overfitting in machine learning models.
- To study probability and Bayes learning and their applications in machine learning.
- To explore logistic regression and support vector machines (SVM) for classification tasks.
- To study neural networks, including perceptron, multilayer networks, and backpropagation algorithm, deep neural networks and applications.
- To explore recurrent neural networks (RNN) and long short-term memory (LSTM) networks, clustering techniques such as k-means and adaptive hierarchical clustering.
- To study Gaussian mixture models for clustering.

Course Contents:

1) Basic definitions, types of learning, hypothesis space and inductive bias, evaluation, cross validation.
2) Linear regression, Decision trees, overfitting.
3) Instance based learning, Feature reduction, Collaborative filtering-based recommendation.
4) Probability and Bayes learning.
5) Logistic Regression, Support Vector Machine, Kernel function and Kernel SVM.

6) Neural network: Perceptron, multilayer network, backpropagation, introduction to deep
7) neural network, RNN and LSTM.
8) Clustering: k-means, adaptive hierarchical clustering, Gaussian mixture model.

References Books:

- Tom Mitchell, Machine Learning. 1st Edition, McGraw- Hill, 1997.
- Ethem Alpaydin, Introduction to Machine Learning, 2nd Edition, The MIT Press, 2009.

MTE 30: Artificial Intelligence

Course Description:

Artificial Intelligence is a course that introduces the fundamental concepts, techniques, and applications of artificial intelligence. The course covers various topics such as the introduction to artificial intelligence, problems and search algorithms, heuristic search techniques, knowledge representation, slot and filler structures, game playing, planning, and learning. The course aims to provide students with a comprehensive understanding of artificial intelligence and its practical applications.

Course Objectives:

- To introduce the concept of artificial intelligence and its significance in various fields, different search and control strategies for problem-solving.
- To study heuristic search techniques such as generate-and-test, hill climbing, best-first search, problem reduction, constraint satisfaction, and mean-ends analysis.
- To understand knowledge representation methods and different approaches to representing knowledge, logical reasoning and representation use propositional and predicate logic.
- To learn about slot and filler structures such as weak structures, semantic networks, frames, strong structures, conceptual dependencies, and scripts.
- To explore game-playing algorithms, including minimax search procedures and alpha-beta cutoffs, planning techniques and their applications, using examples such as the Blocks world.
- To study different learning approaches in artificial intelligence, including rote learning, learning by taking advice, learning from examples, and explanation-based learning.

Course Contents:

1) Introduction to Artificial Intelligence What is AI? Early work in AI, AI and related fields AI problems and Techniques
2) Problems, Problem Spaces and Search: Defining AI problems as a State Space Search: example Production Systems Search and Control Strategies Problem Characteristics Issues in Design of Search Programs Additional Problems
3) Heuristic Search Techniques Generate-and-test, Hill Climbing, Best First Search, Problem Reduction, Constraint Satisfaction, Mean-Ends Analysis
4) Knowledge Representation Representations and Mappings, Approaches to Knowledge Representation, Knowledge representation method, Propositional Logic, Predicate logic,

Representing Simple facts in Logic, Representing Instances and Isa relationships, Computable Functions and Predicates, Resolution, Forward and backward chaining

5) Slot and Filler Structures: Weak Structures, Semantic Networks, Frames, Strong Structures, Conceptual Dependencies, Scripts
6) Game Playing: Minimax Search Procedures, Adding alpha-beta cutoffs
7) Planning: An example Domain: The Blocks world, Component of a planning system, Goal stack planning, Nonlinear planning, Hierarchical Planning
8) Learning: What is learning, Rote Learning, Learning by taking advice, Learning in problem-solving, learning from examples, Explanation-based learning.

Important Note: A teacher is supposed to take the practical implementation of some of the concepts in AI using the Prolog language. Some marks are to be reserved in Continuous Evaluation/Assessment for the laboratory assignments/work.

References Books:

- Artificial Intelligence, Tata McGraw Hill, 2nd Edition, by Elaine Rich and Kevin Knight
- Artificial Intelligence: A Modern Approach by Stuart Russell, Peter Norvig, Prentice Hall.
- Introduction to Artificial Intelligence and Expert System, Prentice Hall of India Pvt. Ltd., New Delhi, 2nd Printing, by Dan Patterson, 1997.
- Introduction to TURBO PROLOG, BPB Publication, by Carl Townsend.

MTE 31: Design and Analysis of Algorithms

Course Description:

Design and Analysis of Algorithms is a course that focuses on designing, analyzing, and implementing efficient algorithms. The course covers various topics such as mathematical foundations for algorithm analysis, sorting algorithms, dynamic programming, greedy algorithms, graph algorithms, sorting networks, parallel algorithms, fast Fourier transform (FFT), number-theoretic algorithms, geometric algorithms, NP-completeness and approximation algorithms. The course aims to provide students with a solid understanding of algorithm design principles and techniques.

Course Objectives:

- To understand the mathematical foundation for analyzing algorithms, including growth functions, summations, recurrences, and counting.
- To study various sorting algorithms such as heap sort, quick sort, merge sort, and sorting in linear time.
- To learn about dynamic programming techniques and their applications in solving problems such as matrix chain multiplication and longest common subsequence.
- To explore greedy algorithms and their use in solving optimization problems.
- Understanding graph algorithms includes traversals, topological sort, minimum spanning trees, single-source shortest paths, all-pairs shortest paths, and maximum flow problems.
- To learn about parallel algorithms and their efficiency in solving problems such as sorting, linear system problems, matrix operations, and matrix inversion.
- To understand the fast Fourier transform (FFT) algorithm and its applications in polynomial multiplication, number-theoretic algorithms such as the Rabin-Karp, KMP, and Boyer-Moore algorithms.
- To study geometric algorithms for problems like finding convex hull, closest pair of points, and linear programming.
- To understand the concepts of P and NP classes, NP-completeness, and reducibility in computational complexity theory.
- To learn about approximation algorithms for solving optimization problems such as the vertex cover problem, traveling salesman problem, set covering, and subset sum problems.

Course Contents:

1) **Mathematical Foundation:** Growth Functions, Summations, Recurrences Substitutions, Iterations, Master Methods, Counting and Probability.
2) **Sorting:** Heap Sort, Quick Sort, Merge Sort, Sorting in linear Time, Medians and Order Statistics.
3) **Dynamic Programming:** Matrix chain Multiplication, longest common subsequence, optimal polygon triangularisation.
4) **Greedy Algorithms**.
5) **Graphs:** Traversals, Topological sort, Minimum spanning trees, single source shortest path, All pair shortest path, Maximum flow problems.
6) **Sorting Networks:** Comparision, bitonic sort and merge sort networks.
7) **Parallel Algorithms:** CRCW, EREW algorithms efficiency sorting linear system problem, Matrix Operations, Strassens Algorithm and matrix inversion.
8) **FFT:** Polynomials DFT, FFT.
9) **Number Theoretic Algorithms:** Rabin - Karp, KMP, Bower - Moore algorithms.
10) **Geometric Algorithms:** Finding convex hall, closes pair of points, linear programming problem.
11) **NP Completeness:** P and NP classes, NP completeness and reducibility.
12) **Approximation Algorithms:** Vertex cover problem, traveling salesman problem, set covering and subset sum problems.

Reference Books:

- T. H Coreman, Leiserson, Rivest, Introduction to Algorithms.
- Berman and Paul, Algorithms, Clngage Learning.

MTE 32: Theory of Computer Science

Course Description:

Theory of Computer Science is a course that focuses on the theoretical foundations of computer science. The course covers various topics such as formal languages, automata theory, context-free languages, pushdown automata, Turing machines, recursive and recursively enumerable languages, and undecidable problems. The course introduces fundamental concepts and techniques in the theory of computation and provides students with a solid understanding of the theoretical aspects of computer science.

Course Objectives:

- To introduce the basic concepts and terminology of formal languages and automata.
- To study regular languages, regular expressions, and finite automata.
- To understand context-free languages, context-free grammars, and pushdown automata, the relationships between different models of computation, such as finite automata, regular grammars, and pushdown automata.
- To introduce Turing machines and their computational power.
- To study the concepts of recursive and recursively enumerable languages.
- To understand the limitations of computation and the concept of undecidability.
- To analyze the halting problem and other undecidable problems using Turing machines, RAM model of computation.
- To solve simple arithmetic problems using Turing machines.

Course Contents:

1) **Preliminaries:** Symbol, Alphabet, String, Prefix and Suffix of Strings, Sets, Operations on sets, Finite and infinite sets, Russells Paradox, Formal Language Relation, Equivalence Relation,(reflexive, transitive and symmetric closures) Principle of Induction
2) **Regular Languages:** Regular Expression: Definition, Examples, and Identities Finite Automata: Concept DFA: Definition and examples NFA: Definition, examples, Language accepted By FA, NFA with e- moves, Regular Expression to FA: Method and Problems NFA with e- moves to NFA,

NFA to DFA: Method Problems: Minimization of DFA: Problem using Table Method, Subset Construction for NFA with e-moves to DFA conversion, Application of FA: Pumping Lemma and Examples Closure Properties: Union, Intersection, -Concatenation, Complement, and Kleene Closure

3) **Context Free Languages -Chomsky Hierarchy -CFG:** Definition and examples, Ambiguous Grammar: Concept and Examples Simplification of CFG: Removing Useless Symbols, removing unit productions and removing Nullable symbols: Methods and Problems, Normal Forms: CNF and GNF: Method and Problems - Regular Grammar: Definition, Equivalence of FA and Regular Grammar

4) **Push Down Automaton:** Basic Concept, Definition (DPDA and PDA) Construction of PDA using empty stack and final State method: Examples using stack method Equivalence between acceptance by final state and Empty stack method and examples Equivalence between PDA and CFG (in GNF): Method and examples Properties of Context-Free Languages Pumping Lemma for CFL: methods and problems, Closure Properties of CFLs(Union, Concatenation, and Kleene Closure: Method and Examples)

5) **Turing Machine -**Recursive and recursively enumerable language -Introduction to LBA (Basic Model) and CSG. -Definition of TM, -Design of TM for language recognition, Types of Turing Machine (Multitape TM, Non-Deterministic TM, Universal TM, Restricted TM) Undecidable Problem, Halting Problem of TM Simple Arithmetic Problems on Unary Numbers using TM, RAM model of computation.

Important Note: The LEX tool on Linux is to be used to address the understanding of the Language and grammar aspects in this course. Few laboratory sessions are expected to be covered. Some marks are to be reserved in Continuous Evaluation/Assessment for the laboratory assignments/work.

References Books:

- John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman, Introduction to Automata Theory, Languages, and Computation 2nd Edition, Pearson Education.
- Peter Linz, Jones & Barlett, An Introduction to Formal Languages and Automata, Student Edition,
- Greenlaw, Hoover, Fundamentals of Theory of Computation, Principals and Practice, Elsevier.
- Daniel I.A. Cohen, Introduction to Computer Theory, 2nd Edition, JohnWiley & Sons (ASIA) Pvt Ltd.
- Thomas A. Sudkamp, An Introduction to the Theory of Computer Science Languages & Machine, 3rd Edition Pearson education.
- John C.Martin, Introduction to Languages and the theory of Computation, 2nd Edition, Tata Mc-Graw Hill Edition.
- K.L.P. Mishra & N. Chandrasekaran, Theory of Computer Science (Automata Languages And Computation, 2nd Edition, Prentice Hall India.

MTE 33: Computer Graphics

Course Description:
Computer Graphics is a comprehensive course that introduces students to the fundamental concepts and techniques used in computer graphics. The course covers various topics, including graphics systems, graphics primitives, color models, programming essentials, TypeScript, version control with GitHub, and various graphics libraries such as three.js and paper.js. Students will learn to create and manipulate 2D and 3D graphics, apply transformations and viewports, work with curves and surfaces, and understand hidden surface elimination and shading models. Additionally, the course will cover important topics such as animation, user interfaces, and basic front-end development.

Course Objectives:

- Gain a solid understanding of computer graphics and its components, including graphics systems, representation, presentation, interaction, and transformations.
- Familiarize yourself with graphics primitives, such as pixels/points, and differentiate between raster and vector graphics. Learn the RGB color model and how to manipulate color intensity in computer graphics.
- Develop programming skills with event-driven programming and libraries like three.js and paper.js for creating interactive graphics.
- Acquire a strong foundation in TypeScript, including basic data structures, object-oriented programming, and implementation of interview programming questions.
- Master the version control system Git and GitHub, understanding concepts such as commits, branches, forking, and resolving merge conflicts.
- Gain proficiency in using three.js, a 3D graphics library, including scene creation, camera setup, rendering pipeline, and geometries like boxes, spheres, and planes.
- Learn to use paper.js, a 2D graphics library, for creating and manipulating 2D paths, animations, and mathematical operations on shapes and curves.
- Understand 2D and 3D transformations and viewing techniques, including translation, rotation, scaling, matrix representations, and clipping operations.
- Study curve and surface representations, including polygon meshes, parametric curves (Hermite, Bezier, B-spline), and their applications in computer graphics.

- Investigate hidden surface elimination techniques, such as depth comparison, Z-buffer algorithm, back-face detection, and wireframe methods.
- Knowledge of color and shading models, including light and color models, interpolative shading, and their use in computer graphics.
- By the end of this course, students will have a strong foundation in computer graphics principles and techniques. They can create and manipulate 2D and 3D graphics, apply transformations and viewports, implement curves and surfaces, and understand hidden surface elimination and shading models. Additionally, students will have practical experience using popular graphics libraries and tools, enabling them to develop interactive graphics applications and contribute to the field of computer graphics.

Course Contents:

1) **Introduction to Computer graphics :** Introduction to computer graphics & graphics systems. Four components of Computer Graphics Representation. Presentation, Interaction and Transformations. Uses of Computer Graphics, Graphics Primitives Pixel/Point, Raster v/s Vector, RGB color model, intensity. Programming essentials event driven programming. three.js library. paper.js library.
2) **Introduction to the typescript :** Fundamentals of typescript programming language with basic data structures. Object oriented programming with typescript. Interview programming questions implementation with typescript. User Interface, basic frontend development with HTML, CSS and javascript.
3) **Introduction to the version control system GitHub:** Learn the key concepts of the Git source control system. Compare the different states in Git and compare branches and commits. Create and fork repositories on GitHub and push changes back after working after working on them locally. Step through the entire Git workflow. Manage files with Git (move, rename, delete) and update files managed outside Git. Create branches and resolve merge conflicts.
4) **Introduction to the 3D graphics library three.js:** Basics of Threejs with many demonstrations and example code three.js Scene, Camera and Renderer. Rendering pipeline. Geometries include Box, Sphere, Icosahedron, Plane, TorusKnot and more. Setting up a Development Environment using VSCode, Git and NodeJS. Create a three.js project using NPM and package json, animation loop, and frame buffers. Object3D base class, the Rotation, Position, Scale, Visibility and Matrix properties, three.js Materials, three.js mesh creation in three.js. Orbit controls.
5) **Introduction to the 2D graphics library paper.js:** Basics of paper.js with demonstration and example code, Paper.js 2D paths, projects and 2D entities, Smoothing, simplifying and flattening the 2D shapes and curves, Vector geometry and mathematical operations on paper.js. Creating animations.
6) **2D Transformations and viewing:** Basic transformations: translation, rotation, scaling; Matrix representations & homogeneous coordinates, Reflection shear; Transformation of points, lines, parallel lines, intersecting lines. Viewing pipeline; Window to the viewport coordinate transformation, clipping operations, point clipping, line clipping; Cohen Sutherland algorithm, Midpoint subdivision algorithm, Cyrus beck algorithm; Polygon clipping, Sutherland Hodgman algorithm, Weiler-Atherton Algorithm.

7) **3D transformation & viewing:** 3D transformations, translation, rotation, scaling & other transformations; Rotation about an arbitrary axis in space, reflection through an arbitrary plane; general parallel projection transformation; Three-dimensional viewing, Parallel and Perspective projections.
8) **Curves and Surfaces:** Polygon meshes, Representing polygons; Parametric curves, Hermite Curves, Bezier curves, B-spline curves.
9) **Hidden surfaces Elimination:** Depth comparison, Z-buffer algorithm, Back face detection, BSP tree method, the Painter's algorithm, scan-line algorithm, Hidden line elimination, wireframe methods, fractal geometry. Color & shading models Light & color model, interpolative shading model.

Important Note:
Students are expected to implement the algorithms/assignments taught in this course using three.js/paper.js using javascript on the Windows platform. Some marks are to be reserved in Continuous Evaluation / Assessment for the laboratory assignments/work.

References Books:

- Hearn, Baker Computer Graphics, C version,2nd Edition, Pearson Education https://r105.threejsfundamentals.org/threejs/lessons/threejs-fundamentals.html http://paperjs.org/tutorials/
- Foley, Vandam, Feiner, Hughes Computer Graphics principles 2nd Edition, Pearson Education. 26
- W. M. Newman, R. F. Sproull Principles of Interactive Computer Graphics TMH.
- D. F. Rogers, J. A. Adams Mathematical Elements for Computer Graphics, 2nd Edition, TMH
- F S. Hill, Stephen Kelly, Computer Graphics using OpenGL, PHI Learning
- Z. Xiang, R. Plastock Schaum's outlines Computer Graphics, 2nd Edition, TMH.

MTE 34: Image Processing

Course Description:
Image Processing is an advanced course exploring the principles and techniques of digital image processing. The course covers a wide range of topics, including evolutionary computing and its applications, as well as the fundamentals of digital image processing. Students will learn about image acquisition, sampling, quantization, and the relationships between pixels. They will also study various image enhancement techniques in spatial and frequency domains. Also, the course covers morphological image processing, image segmentation, and representation and description methods for shapes and textures.

Course Objectives:
- Understand the principles and applications of evolutionary computing and its various techniques, such as genetic algorithms, ant colony optimization, Monte Carlo methods, and simulated annealing.
- Learn about selection strategies and search operators, including crossover and mutation, and their role in evolutionary algorithms.
- Study the principles and techniques of digital image processing, including image acquisition, sampling, and quantization.
- Gain practical knowledge of image enhancement techniques such as the discrete Fourier transform (DFT), frequency-domain filters like Ideal, Butterworth, and Gaussian filters, and morphological image processing operations such as dilation, erosion, opening, closing, and hit-or-miss transform.
- Learn about image segmentation techniques, including discontinuity detection, point, line, edge detection, and region-based segmentation methods.
- Understand the representation and description of shapes in digital images, including chain codes, polygonal approximations, signatures, skeletons, Fourier descriptors, statistical moments, and texture descriptors.

- Gain practical knowledge of image analysis techniques, such as boundary extraction, region filling, and regional and topological descriptors.
- Explore the concept of texture in images and learn how to analyze and describe texture using appropriate techniques.
- By the end of this course, students will have a strong foundation in evolutionary computing and digital image processing techniques. They can apply various image enhancement, segmentation, and analysis techniques to solve real-world problems. Additionally, students will gain practical skills in using software tools and libraries commonly used in image processing applications, enabling them to pursue careers in computer vision, medical imaging, and multimedia processing.

Course Contents:

1) **Introduction:** What Is Digital Image Processing?, MATLAB and the Image Processing Toolbox
2) **Fundamentals:** Digital Image Representation, Reading Images, Displaying Images, Writing Images, Classes, Image Types, Converting between Classes, Array Indexing, Indexing Vectors, Some Important Standard Arrays, Introduction to M-Function Programming
3) **Intensity Transformations and Spatial Filtering:** Intensity Transformation Functions, Histogram Processing and Function Plotting, Spatial Filtering, Image Processing Toolbox , Standard Spatial Filters, Using Fuzzy Techniques for Intensity Transformations and Spatial Filtering
4) **Filtering in the Frequency Domain:** The 2-D Discrete Fourier Transform, Computing and Visualizing the 2-D OF T in MATLAB, Filtering in the Frequency Domain, Obtaining Frequency Domain Filters from Spatial Filters, Generating Filters Directly in the Frequency Domain, Highpass (Sharpening) Frequency Domain Filters, Selective Filtering
5) **Image Restoration and Reconstruction:** A Model of the Image Degradation/Restoration Process, Noise Models, Restoration in the Presence of Noise Only-Spatial Filtering, Periodic Noise Reduction Using Frequency Domain Filtering, Modeling the Degradation Function, Direct Inverse Filtering, Wiener Filtering, Constrained Least Squares (Regularized) Filtering, Iterative Nonlinear Restoration Using the Lucy-Richardson Algorithm, Blind Deconvolution, mage Reconstruction from Projections,
6) **Geometric Transformations and Image:** Transforming Points, Affine Transformations, Projective Transformations, Applying Geometric Transformations to Images, Image Coordinate Systems in MATLAB, Image Interpolation, Image Registration
7) **Colour Image Processing:** Colour Image Representation in MATLAB, Converting Between Colour Spaces, The Basics of Colour Image Processing, Colour Transformations, Spatial Filtering of Colour Images, Working Directly in RGB Vector Space
8) **Wavelets:** Background, The Fast Wavelet Transform, Working with Wavelet, Decomposition Structures, The Inverse Fast Wavelet Transform, Wavelets in Image Processing
9) **Image Compression:** Background, Coding Redundancy, Spatial Redundancy, Irrelevant Information, JPEG Compression, Video Compression,

10) **Morphological Image Processing:** Preliminaries, Dilation and Erosion, Combining Dilation and Erosion, Labeling Connected Components, Morphological Reconstruction, Gray-Scale Morphology

11) **Image Segmentation:** Point, Line, and Edge Detection, Line Detection Using the Hough , Transform, Thresholding, Region-Based Segmentation, Segmentation Using the Watershed Transform

References Books:

- Gonzalez, R. C., Woods, R. E., and Eddins, S. L., Digital Image Processing using MATLAB, 2nd ed., Gatesmark Publishing, Knoxville, TN, 2009.
- Gonzalez, R. C. and Woods, R. E., Digital Image Processing, 2nd /3rd Edition, Prentice Hall, 2002/2008.
- Sonka, M., Hlavac, V., and Boyle, R., Image Processing, Analysis and Machine Vision, 2nd Edition, PWS Publishing.
- Anil K. Jain, Fundamentals of digital image processing 2nd Edition, Prentice- Hall, NJ, 2001.

The departmental committee will decide on the syllabus for the following subjects as per the need and demands of the current industry/research institutes' requirements.

MTE-35	Topics in Discrete Mathematics-I	4
MTE-36	Topics in Computational Mathematics	4
MTE-37	Topics in Computer Science-I	4
MTE-38	Topics in Algebra-I	4
MTE-39	Topics in Analysis-I	4
MTE-40	Topics in Applied Mathematics	4
MTE-41	Online Courses SWAYAM/NPTEL/Any other Elective Courses approved by the Departmental Committee of the Department	4