# Savitribai Phule Pune University

*(Formerly University of Pune)*

**Two Year Post Graduate Degree Programme in Mathematics**

**(Faculty of Science & Technology)**

New Syllabi

for

**M.Sc.- Mathematics Part-I**

**(For Colleges Affiliated to Savitribai Phule Pune University, Pune)**

**(As per National Education Policy- 2020)**

**To be implemented from the Academic Year 2023-2024.**

# Preamble

The board of studies in Mathematics of Savitribai Phule Pune University, Pune made a rigorous attempt to revise the curriculum of postgraduate Programme M.Sc. to align it with National Education Policy-2020 and UGC Quality Mandate for Higher Education Institutions-2021. The process of revamping the curriculum started with the series of Meetings, workshops, webinars and discussions with sub-committees conducted by the University to orient the teachers about the key features of the Education Policy, enabling them to revise the curriculum in sync with the Policy. Appropriate orientation of the faculty about the vision and provisions of NEP-2020 made it easier for them to appreciate and incorporate the vital aspects of the Policy in the revised curriculum focused on ‘creating holistic, thoughtful, creative and well-rounded individuals equipped with the skill sets of 21st century for the ‘development of an enlightened, socially conscious, knowledgeable, and skilled citizen of the nation’.

With NEP-2020 in background, the revised curricula will articulate the spirit of the policy by emphasizing upon- integrated approach to learning; innovative pedagogies and assessment strategies; multidisciplinary and Interdisciplinary education; creative and critical thinking; student-centric participatory learning; imaginative abilities and flexible curricular structures to enable creative combination of disciplines for the study. The Credit framework for designing Post Graduate Programme prepared by the University as per the guidelines of State Government is followed as it is and the curriculum is further modified as per the needs specified in NEP. The curriculum is developed to trigger the inquisitiveness, discussion, analytical ability and quest for discovery among learners. Mathematics is a powerful tool for understanding and communicate globally that organizes our lives and prevents chaos, which helps us understand the world and provides an effective way of building mental discipline. Along with mathematical skills, it is also expected that students will learn life skills like argumentation, communication and general social values which are necessary to life rich, productive and meaningful life. Additionally, the knowledge of mathematical modelling and computational training which the students acquire during the Programmemakes them highly sought after. In keeping with the demands of industry and academia, the syllabus is updated regularly, with inputs taken from various stakeholders including students, alumni and parents at different stages of the modification/addition of the syllabus. The new curriculum provides a synoptic overview of possible career paths mapped by a postgraduate degree in Mathematics Teaching, Research, Engineering, Computer Programming, Statistician, Competitive examination, and many more.

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# Important Highlights

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

(2) **Duration**: 02 years (Four semesters) Full-time Post - Graduate Degree Programme

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

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

(5) **Programme 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 Programme 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) Each course of 4 credits, other than OJT and RP.

(d) 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.

(e) 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.

(f) The Department may conduct necessary lectures/workshops as a part of OJT.

(I) 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 Separately. There will be Continuous Assessment (CA) and End Term Examination for each course.

(II) 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

(III) For passing a course, a student has to score a minimum of 40% marks in each of the CA and ETE separately and a minimum of 40% marks in the combined grading of CA and ETE. If a student fails to score a minimum of 40% marks in CA or ETE in a course, then the result of such a course will be FAIL.

(IV) 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

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.

(6) **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 Programme. In this case, the student will be conferred with PG Diploma in Mathematics.

(7) **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) Programme must have earned at least 22 credits from the total credits of two semesters of the first year of M. A./M.Sc. (Mathematics).

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

**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.

(9) **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 College/ University and Government of Maharashtra.

10) **Eligibility:**(B.Sc. / B. A.) Mathematics/(B. Sc./ B. E./ B. Tech.) with Mathematics subject at least at second year).

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# ProgrammeOutcomes(POs)

**Name of the Programme: M.Sc. Mathematics**

| **PO-No.** | **ProgrammeOutcomes**<br>*The Student will be* | **Component** |
|---|---|---|
| **PO-1** | Capable of delivering basic disciplinary knowledge gained during the Programme. | Basic Knowledge |
| **PO-2** | Capable of describing advanced knowledge gained during the Programme | In-depth Knowledge |
| **PO-3** | Able to gain knowledge with the holistic and multidisciplinary approach across the fields. | Holistic and multidisciplinary Education |
| **PO-4** | Capable of analyzing the results critically and applying acquired knowledge to solve the problems | Critical thinking and Problem-Solving abilities |
| **PO-5** | Capable to identify, formulate, investigate and analyze the scientific problems and innovatively design and create product solutions to professional and real life problems. | Creativity and innovation |
| **PO-6** | Able to develop a research aptitude and apply knowledge to find the solution of burning research problems in the concerned and associated fields at global level. | Research aptitude and global Competency |
| **PO-7** | Able to Learn interdisciplinary and multidisciplinary skill sets and advanced techniques to apply them for better livelihood of mankind. | Skills enhancement |
| **PO-8** | able to learn and work in a groups and capable of leading a team even. | Leadership and Teamwork abilities |
| **PO-9** | Able to acquire lifelong learning skills which will lead important to better opportunities and improve quality of life. | Environmental and human health awareness |
| **PO-10** | Inculcate the professional and ethical attitude and ability to relate with social problems. | Ethical thinking and Social awareness |
| **PO-11** | Capable to establish independent start-up/innovation Centre etc. | Lifelong learning skills and Entrepreneurship |

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# ProgrammeSpecific Outcomes(PSOs)

| PSO. No. | **ProgrammeSpecific Outcomes**<br>*The student-* |
|---|---|
| **PSO-1** | will have a strong foundation in both pure and applied mathematics. |
| **PSO-2** | will have the knowledge of the fundamental axioms in mathematics and capability of developing ideas based on them and inculcate mathematical reasoning. |
| **PSO-3** | will be able to apply mathematical skills for solving problems and can prepare himself forvarious competitive exams. |
| **PSO-4** | will acquire the knowledge of a wide range of mathematical techniques and application of mathematical methods/tools in science, social science, engineering and technology |
| **PSO-5** | will have basic knowledge of Programming and computational techniques as required for employment. |
| **PSO-6** | will be able to develop analytical skills, critical thinking, creativity, communication, and presentation skills through assignments, seminars, Training, and Research project. |

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## Course StructureoftheProgramme:M.Sc./ M.A. Mathematics Part- I

## Approved by B.O.S.

## 2023-24

| Year | Level | Sem. | Course Type | CourseCode | CourseTitle | Remark | Credit | No. ofHours |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.0 | I | Core | MTS-501MJ | LinearAlgebra | Theory | 2 | 30 |
| | | | Core | MTS-502 MJP | Practical Based on Linear Algebra | Practical | 2 | 60 |
| | | | Core | MTS-503 MJ | GroupTheory | Theory | 4 | 60 |
| | | | Core | MTS-504 MJ | Ordinary differential Equations | Theory | 4 | 60 |
| | | | Core | MTS-505 MJ | Programming withPython | Practical | 2 | 60 |
| | | | Elective (Choose Any one) | MTS-506(A)MJ | Advanced Numerical Analysis | Theory | 2 | 30 |
| | | | | MTS-507(A)MJP | Practical Based on Advanced Numerical Analysis | Practical | 2 | 60 |
| | | | | MTS-506(B)MJ | NumberTheory | Theory | 2 | 30 |
| | | | | MTS-507(B)MJP | Practical Based on Number Theory | Practical | 2 | 60 |
| | | | | MTS-506(C)MJ | Combinatorics | Theory | 2 | 30 |
| | | | | MTS-507(C)MJP | Practical Based on Combinatorics | Practical | 2 | 60 |
| | | | | MTS-506(D)MJ | Lattice Theory | Theory | 2 | 30 |
| | | | | MTS-507(D)MJP | Practical Based on Lattice Theory | Practical | 2 | 60 |
| | | | RM | MTS-508 MJ | Research Methodology | Theory | 2 | 30 |
| | | | | MTS-509 MJP | Practical based on Research Methodology | Practical | 2 | 60 |
| | | | Core | MTS-551MJ | Topology | Theory | 2 | 30 |
| | | | Core | MTS-552 MJP | Practical Based on Topology | Practical | 2 | 60 |
| | | | Core | MTS-553 MJ | Ring Theory | Theory | 4 | 60 |
| | | | Core | MTS-554 MJ | AdvancedCalculus | Theory | 4 | 60 |

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|---|---|---|---|---|---|---|---|---|
| | | II | Core | MTS-555 MJP | Data Science | Practical | 2 | 60 |
| | | | Elective (Choose any one) | MTS-556(A)MJ | GraphTheory | Theory | 2 | 30 |
| | | | | MTS-557(A)MJP | Practical Based on Graph Theory | Practical | 2 | 60 |
| | | | | MTS-556(B)MJ | DynamicalSystems | Theory | 2 | 30 |
| | | | | MTS-557(B)MJP | Practical Based on DynamicalSystems | Practical | 2 | 60 |
| | | | | MTS-556(C)MJ | CodingTheory | Theory | 2 | 30 |
| | | | | MTS-557(C)MJP | Practical Based onCodingTheory | Practical | 2 | 60 |
| | | | | MTS-556(D)MJ | Operations Research | Theory | 2 | 30 |
| | | | | MTS-557(D)MJP | Practical Based on Operations Research | Practical | 2 | 60 |
| | | | OJT/FP | MTS-558 MJP | On Job Training or Field Project | Practical | 4 | 120 |

## Course StructureoftheProgramme:M.Sc./M.A. Mathematics Part- II 2024-25

| Year | Level | Semester | Course Type | Course Code | CourseTitle | Remark | Credit | No. of Hours |
|---|---|---|---|---|---|---|---|---|
| 2 | 6.5 | III | Core | MTS-601MJ | Complex Analysis | Theory | 2 | 30 |
| | | | Core | MTS-602 MJP | Practical Based on Complex Analysis | Practical | 2 | 60 |
| | | | Core | MTS-603 MJ | Field Theory | Theory | 4 | 60 |
| | | | Core | MTS-604 MJ | Differential Geometry | Theory | 4 | 60 |
| | | | Core | MTS-605 MJ | Machine learning using Python | Practical | 2 | 60 |
| | | | Elective (Choose any one) | MTS-606(A)MJ | Mathematical Statistics | Theory | 2 | 30 |
| | | | | MTS-607(A)MJP | Practical Based on Mathematical Statistics | Practical | 2 | 60 |
| | | | | MTS-606(B)MJ | Algebraictopology | Theory | 2 | 30 |
| | | | | MTS-607(B)MJP | Practical Based onAlgebraictopology | Practical | 2 | 60 |
| | | | | MTS-606(C)MJ | Integral Transforms and Boundary Value Problem | Theory | 2 | 30 |
| | | | | MTS-607(C)MJP | Practical Based on Integral Transforms andBoundary Value Problem | Practical | 2 | 60 |
| | | | | MTS-606(D)MJ | Mechanics | Theory | 2 | 30 |
| | | | | MTS-607(D)MJP | Practical Based on Mechanics | Practical | 2 | 60 |
| | | | RP | MTS-608 MJ | Research Project | Practical | 4 | 120 |
| | | | Core | MTS-651MJ | Function Alanalysis | Theory | 2 | 30 |
| | | | | MTS-652 MJP | Practical based on Functional Analysis | Practical | 2 | 60 |
| | | | Core | MTS-653 MJ | Partial DifferentialEquations with Boundary Value Problems | Theory | 4 | 60 |
| | | | Core | MTS-654 MJ | Measure Theory and Integration | Theory | 4 | 60 |

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|---|---|---|---|---|---|---|---|---|
| | | IV | Elective (Choose any one) | MTS-656(A)MJ | CommutativeAlgebra | Theory | **2** | 30 |
| | | | | MTS-657(A)MJP | Practical based onCommutativeAlgebra | Practical | **2** | 60 |
| | | | | MTS-656(B)MJ | Financial Mathematics | Theory | **2** | 30 |
| | | | | MTS-657(B)MJP | Practical based onFinancial Mathematics | Practical | **2** | 60 |
| | | | | MTS-656(C)MJ | Algebraic Curves | Theory | **2** | 30 |
| | | | | MTS-657(C)MJP | Practical based onAlgebraic Curves | Practical | **2** | 60 |
| | | | | MTS-656(D)MJ | Optimization Techniques | Theory | **2** | 30 |
| | | | | MTS-657(D)MJP | Practical based onOptimization Techniques | Practical | **2** | 60 |
| | | | RP | MTS-655 RP | ResearchProject | Practical | **6** | 180 |

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# Details of Syllabus:

## Semester-I

### MTS-501MJ & MTS 502 MJP: Linear Algebra [ 2T +2P=04 Credits ]

**Course Objectives:**

1. To make students understands the concept of Vectors and Vector Spaces
2. To impart the Applications of Eigen values and Eigen Vectors in various fields like Cryptography, Economics, Computer Graphics etc.
3. To make students understand the applicability of Matrices in Linear Algebra
4. To teach the Utility / Practical use of Linear Transformation
5. To make student aware about Linear Algebra and its Applications
6. To interpret the various forms of data using Linear Algebra

**Course Outcomes:**

1. Can imagine the results of basic operations on vectors in $\mathbb{R}^2, \mathbb{R}^3$ geometrically and differentiate between Finite and Infinite Dimensional Vector Spaces
2. Can differentiate between Eigen Values and Eigen Vectors along with its Applications along with real life examples of the difference between Linear and Non – Linear Transformation
3. Can recognize the invariant and Non – invariant subspaces under the given linear operator
4. Can apply the Cayley – Hamilton Theorem to calculate the values of matrices that are raised to a large exponent
5. Can understand the construction of Inner Product Spaces and Bilinear spaces
6. Can tell the applications of Linear Algebra to real life

**Course Contents:**

**Unit 1. Vector Spaces** **[12 Hours]**

1.1 Vector Spaces
1.2 Subspaces
1.3 Bases and Dimension
1.4 Coordinates
1.5 Applications in Cryptography
1.6 Applications in Economics

**Unit 2.Linear Transformation** **[15 Hours]**

2.1 Linear Transformations
2.2 The Algebra of Linear Transformations
2.3 Isomorphism
2.4 Representation of Transformations by Matrices
2.5 Linear Functionals
2.6 The Double Dual

**Unit 3.Elementary Canonical Forms** **[15 Hours]**

3.1 Introduction
3.2 Characteristic Values
3.3 Annihilating Polynomials
3.4 Invariant Subspaces and Diagonalization

**Unit 4.The Rational and Jordan Forms** **[15 Hours]**

4.1 Cyclic Subspaces and Annihilators
4.2 Cyclic Decomposition and the Rational Form
4.3 The Jordan Form

**Unit 5.Inner Product Spaces** **[15 Hours]**

5.1 Inner Products
5.2 Inner Product Spaces
5.3 Linear Functionals and Adjoints
5.4 Unitary Operators
5.5 Normal Operators

**Unit 6 Bilinear Forms** **[18 Hours]**

6.1 Bilinear Forms
6.2 Symmetric Bilinear Forms
6.3 Skew – Symmetric Bilinear Forms
6.4 Application to Input-Output Economic Models
6.5 Application to Markov Chain

**Recommended Book:**

1. **K. Hoffman and R. Kunze**, Linear Algebra, 2nd Edition [Prentice Hall of India Pvt. Ltd.]
   Unit 1: 2.1 – 2.4, Unit 2: 3.1 – 3.6, Unit 3: 6.1 – 6.4, Unit 4: 7.1 – 7.3, Unit 5: 8.1 – 8.5, Unit 6: 10.1 – 10.3
2. **Applications:**
   1.5 [2.5 Applied Finite Mathematics by R. Sekhon and R. Bloom, Libre Texts]
   1.6 [2.6 Applied Finite Mathematics by R. Sekhon and R. Bloom, Libre Texts]
   6.4 [2.8 LINEAR ALGEBRA with Applications, by W. Keith Nicholson]
   6.5 [2.9 LINEAR ALGEBRA with Applications, by W. Keith Nicholson]

**Reference Books:**

1. **P B Bhattacharya, S K Jain and S R Nagpaul** :A First Course in Linear Algebra [New Age International Publishers].
2. **Vivek Sahai and Vikas Bist** Linear Algebra [Narosa Publishing House].
3. **S. Kumaresan**Linear Algebra: A Geometrical Approach [PHI Learning Pvt., Ltd.]
4. **A. R. Rao and P. Bhimasankaram** Linear Algebra [Tata McGraw – Hill Publishing Company Ltd., New Delhi]
5. **Kuldeep Singh,** Linear Algebra Step by Step [Oxford University Press]

## MTS-503 MJ: Group Theory **[04 Credits]**

**Course Objectives:** *Students will*

1. learn group and subgroup.
2. learn cyclic group and properties of permutations.
3. learn external direct product of a finite number of groups.
4. learn group homomorphism and Cayley's theorem.
5. learn isomorphism and their properties.
6. learn Sylow theorems and their applications.

**Course Outcomes:**

1. Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.
2. Identify the various algebraic structures with their corresponding binary operations.
3. Learn about structure preserving maps between groups and their consequences.
4. Analyze consequences of Lagrange's theorem.
5. Apply Sylow theorems for groups of finite orders.
6. Explain the significance of the notion of cosets, normal subgroups, and factor groups.

**Course Contents:**

**Unit 1. Introduction to Groups** **[16 Hours]**

1.1 Basic Axioms and Examples.
1.2 Dihedral Groups
1.3 Symmetric Groups
1.4 Matrix Groups
1.5 The Quaternion Group.
1.6 Homomorphism and Isomorphisms.
1.7 Group Actions.

**Unit 2. Subgroups** **[12 Hours]**

2.1 Definition and Examples.
2.2 Centralizers and Normalizers, Stabilizers and Kernels.
2.3 Cyclic Groups and Cyclic Subgroups.
2.4 Subgroups Generated by Subsets of a Group.
2.5 The Lattice of Subgroups of a Group.

**Unit 3 Quotient Groups and Homomorphisms** **[10 Hours]**

3.1 Definition and Examples.
3.2 More on Cosets and Lagrange's Theorem.
3.3 The Isomorphism Theorems.
3.4 Composition Series.
3.5 Transpositions and Alternating Group.

**Unit 4 Sylow Theorems and Group Actions [08 Hours]**

4.1 Group Actions and Permutation Representations.

4.2 Group Acting on Themselves by Left Multiplication – Cayley's Theorem.

4.3 Group Acting on Themselves by Conjugation – The Class Equation.

4.4 Automorphisms.

4.5 The Sylow Theorems.

4.6 The Simplicity of $A_n$.

**Unit 5 Direct and Semidirect Products and Abelian Groups [14 Hours]**

5.1 Direct Products.

5.2 The Fundamental Theorem of Finitely Generated Abelian Groups.

5.3 Table of Groups of Small order.

5.4 Recognizing Direct Products

5.5 Semidirect Product.

**Recommended Book:**

**David S. Dummit, Richard M. Foote**, Abstract Algebra, 3rd Edition, John Wiley and Sons (Indian Edition).Chapter-1, 2, 3(Expect Holder Programme), 4, 5.

**Reference Books:**

1**. Joseph Gallian**, Contemporary Abstract Algebra, 9th Edition, Cengage Learning India Pvt. Ltd. ISBN-109360502527

2. **P.B. Bhattacharya, S.K.Jain and S.R. Nagpaul,** Basic Abstract Algebra (Cambridge University Press, Second Edition), 1995 (Indian Edition).

3. **I. S. Luthar, I. B. S. Passi**, Algebra (Vol 1), Groups; Narosa Publication House.

4. **I. N. Herstein**, Topics in Algebra, Wiley Eastern Ltd.

5. **J. B. Fraleigh**, A First Course in Abstract Algebra, 7th Edition, Pearson EditionLtd.

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## MTS-504 MJ: Ordinary Differential Equations [04 Credits]

**Course Objectives:**

1. This course aims at providing knowledge of ordinary differential equations.
2. A student should be able to apply skills and knowledge to translate information presented verbally into differential equations form. Analyze and use appropriate methods to obtain the solution.
3. A student should get adequate exposure to global and local concerns that explore many aspects of differential equations.
4. A student should be able to solve the mathematical models occurring in various fields which contain differential equations.

**Course Outcomes:**

1. Studentsareabletofindsolutionsoflinearequationsoffirstorder.
2. Students can find solutions for homogeneous and non-homogeneous equationsofsecond order.
3. ExplainEuler'sequation,Legendre'sequation,andBessel'sequation.
4. Understand the ExistenceandUniquenessofsolutions.
5. Students learn a system of differential equations.

**Course Contents:**

**Unit 1 : Linearequationswithconstantcoefficients:** **[14 Hours]**

1.1 Linearequationsofthefirstorder
1.2 Theequationy'+ay=0
1.3 Theequationy'+ay=b(x)
1.4 Thegenerallinearequationsoffirstorder
1.5 Secondorderhomogeneousequations
1.6 Initialvalueproblemsforsecondorderequations
1.7 Lineardependence,andindependence
1.8 FormulafortheWronskian
1.9 Non-homogeneousequationsofordertwo
1.10 Homogeneousequationsofordern
1.11 Non-homogeneousequationsofordern
1.12 Algebraofconstantcoefficientsequations

**Unit 2:Linearequationswithvariablecoefficients:** **[12 Hours]**

2.1 Initialvalueproblemsforthehomogeneousequation
2.2 Solutionsofthehomogeneousequation
2.3 Wronskianandlinearindependence
2.4 Reductionof the orderofthehomogeneousequation
2.5 non-homogeneousequations
2.6 Homogeneousequations with analytic coefficients
2.7 The Legendreequation

**Unit 3 LinearEquationswithregularsingularpoints:** **[10 Hours]**

3.1 The Euler equation
3.2 Secondorderequationwithregularsingularpoints
3.3 The exceptionalcases
3.4 The Besselequation
3.5 Regularsingularpointatinfinity

**Unit 4 Existence and uniqueness of solutions to first-order equations:** **[10 Hours]**

4.1 Equations with variables separated
4.2 Exactequations
4.3 Methodofsuccessiveapproximations
4.4 Lipschitzcondition
4.5 Approximationto,andUniquenessof,solutions

**Unit 5System of First-Order Equations:** **[14 Hours]**

5.1 First-order systems
5.2 Linear first-order systems
5.3 Constant systems – eigenvalues and eigenvectors
5.4 Nonhomogeneous systems
5.5 System as a vector equation
5.5 Existence and uniqueness of solutions of a system
5.6 Existence and uniqueness of linear systems

**Recommended Book:**

1. **E. A. Coddington**, An Introduction to Ordinary Differential Equations(Prentice-Hall).

Unit 1 : Chapter 1: sections 4 to 7, Chapter 2: sections 1 to 7, 10, 12.

Unit 2 : Chapter 3 : sections 1 to 8. Unit 3 : Chapter 4: sections 1 to 3 , 6, 7, 9.

Unit 4 : Chapter 5 : sections 1 to 5 , 8. Unit 5: Chapter 6 : section 1, 5, 6, 7.

2. **Shair Ahmad Antonio Ambrosetti**, A Text Book on Ordinary Differential Equations, Second Edition, SpringerUnit 5: Chapter 7: 7.1 (revision) 7.2 to 7.6

**Reference Books:**

**G.F.Simmons and S.G.Krantz,** Differential Equations(TataMcGraw-Hill).

## MTS-505 MJP :Programming with Python [2P Credits]

**Course Objectives:**

1. Prime objective is to give students a basic introduction to Programming and problem solving with computer language Python. And to introduce students not merely to the coding of computer Programmes, but to computational thinking, the methodology of computer Programming, and the principles of good Programme design including modularity and encapsulation.
2. To understand problem solving, problem solving aspects, Programming and to know about
3. various Programme design tools.
4. To learn problem solving with computers.
5. To learn basics, features and future of Python Programming.
6. To acquaint with data types, input output statements, decision making, looping and
7. functions in Python.

**Course Outcomes:**

1. Inculcate and apply various skills in problem solving.
2. Choose most appropriate Programming constructs and features to solve the problems in diversified domains.
3. Exhibit the Programming skills for the problems those require the writing of well-documented Programmes including use of the logical constructs of language, Python.
4. Demonstrate significant experience with the Python Programme development environment.
5. To learn features of Object Oriented Programming using Python.
6. To acquaint with the use and benefits of files handling in Python.

**Course Contents:**

**Unit 1 Revision** **[12Hours]**

Variables and Simple Data Types
1.1 Variables
1.2 Strings
1.3 Numbers
Introducing Lists
1.4 What is a List?
1.5 Changing, Adding and Removing Elements
1.6 Organizing a List
1.7 Looping Through an Entire List
1.8 Avoiding Indentation Errors
1.9 Making Numerical Lists
1.10 Working with Part of a List

1.11 Tuples
If Statements
1.12 Conditional Tests
1.13 If Statements
1.14 Using if Statements with Lists
Dictionaries
1.15 Working with Dictionaries
1.16 Looping Through a Dictionary
1.17 Nesting

**Unit 2: User Input and While Loops** **[12 Hours]**

2.1 How the input () Function works
2.2 Introducing while Loops
2.3 Using a while Loop with Lists and Dictionaries

**Unit 3 :Functions** **[12 Hours]**

3.1 Defining a Function
3.2 Passing Arguments
3.3 Return Values
3.4 Passing a List
3.5 Passing an Arbitrary Number of Arguments
3.6 Storing Your Functions in Modules

**Unit 4 :Classes** **[12 Hours]**

4.1Creating and using a Class
4.2 Working with Classes and Instances
4.3 Inheritance
4.4 Importing Classes

**Unit 5 :Files and Exceptions** **[12 Hours]**

5.1Reading from a File
5.2 Writing to a File
5.3 Exceptions
5.4 Storing Data

**Recommended Book:**

**Eric Matthes,**Python Crash Course 2nd Edition.
Chap 2-10.

**Reference Books:**

1. **Magnus Lie Hetland**Beginning Python, From Novice to Professional Third Edition
2. **Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser**: Data Structures & Algorithms in Python

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## MTS-506(A)MJ & 507(A)MJP : Advanced Numerical Analysis [ 2T +2P=04 Credits ]

**Course Objectives:**

1. To introduce the numerical techniques for solving the rootfinding problems, systems of linear equations.
2. To comprehend the numerical techniques for approximating the eigenvalues and eigenvectors of $n \times n$ matrix.
3. To introduce the polynomial interpolation , numerical techniques of differentiation and integration.
4. To acquaint the students with the knowledge of various numerical techniques and methods of solving ordinary differential equations.

**Course Outcomes:**

1. Solve the rootfinding problems with an arbitrary nonlinear function.
2. Use the direct and iterative techniques for the solution of systems of linear algebraic equations.
3. Determine the value of the interpolating polynomial at a single value of the independent variable.
4. Apply the numerical techniques of differentiation and integration for engineering problems.
5. Understand various numerical techniques for approximating the solution of initial value problems of ordinary differential equations.

**Course Contents:**

**Unit 1. Root Finding Methods:** **[12 Hours]**

1.1 Convergence; Floating Point Number Systems; Floating Point Arithmetic.

1.2 Fixed Point Iteration Schemes; Newton's Method; Secant Method; Accelerating Convergence.

**Unit 2. System of Equations:** **[20 Hours]**

2.1 Gaussian Elimination; Pivoting Strategies, Vector and matrix norms.

2.2 Error Estimates and Condition Number; LU decomposition; Direct Factorization.

2.3 Iterative Techniques for Linear Systems: Basic Concepts and Methods.

**Unit 3. Eigenvalues and Eigenvectors** **[12 Hours]**

3.1 The Power Method

3.2 The Inverse Power Method.

3.3 Reduction to Symmetric Tridiagonal Form.

3.4 Eigenvalues of Symmetric Tridiagonal Matrices.

**Unit 4. Interpolation (and curve fitting** **[12 Hours]**

4.1 Lagrange Form Of The Interpolating Polynomial

4.2 Neville's Algorithm

4.3 The Newton Form Of The Interpolating Polynomial

4.4 Optimal Points For Interpolation

**Unit 5. Differentiation and Integration** **[16 Hours]**

5.1Numerical Differentiation, Part II

5.2 Numerical Integration – The Basics and Newton-Cotes Quadrature; Composite Newton-Cotes Quadrature

**Unit 6. Initial Value Problems of Ordinary Differential Equations** **[18 Hours]**

6.1 Euler's Method; Higher-Order One-Step Methods: Taylor Methods.

6.2 Runge-Kutta Methods.

6.3 Multistep Methods.

6.4 Convergence and Stability Analysis.

**Recommended Book:**

**Brian Bradie**, A Friendly Introduction to Numerical Analysis, Pearson Prentice Hall, Eleventh impression, ISBN 978-81-317-0942-9.

Sections: 1.2 – 1.4, 2.3 – 2.6, 3.1 – 3.6, 3.8, 4.1, 4.2, 4.4, 4.5, 5.1–5.4, 6.2, 6.4, 6.5, 7.2 – 7.6

**Reference Books:**


1) **K.E. Atkinson**, An Introduction to Numerical Analysis, Second Edition, John Wiley & Sons.
2) **J. L. Buchanan, P. R. Turner**, Numerical Methods and Analysis,McGraw-Hill, New York, N.Y., 1992 cop
3) **M.K. Jain, S.R.K. Iyengar, R.K. Jain,** Numerical Methods for Scientific &Engineering Computation, New Age International, 5th edition.
4) **Grewal, B.S., and Grewal, J.S.,** "Numerical Methods in Engineering and Science", Khanna Publishers, 10th Edition, New Delhi, 2015.
5) **J.N. Sharma**, Numerical Methods for Engine
6) **J.N. Sharma**, Numerical Methods for Engineers and Scientists, Alpha Science, second edition.


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## MTS-506(B)MJ & 507(B)MJP : Number Theory [ 2T +2P=04 Credits ]

**Course Objectives:**

- Recall, define basic concepts of set of integers and divisibility.
- Discuss congruence relation and its applications and use different techniques of numerical calculations.
- Learn different number theoretic functions, and use it for solving problems.
- Understanding Gauss Reciprocity and its use in solving problems.
- Solving linear Diophantine equations and linear congruences.
- Studying Algebraic Number Fields, Algebraic Integers, Quadratic Fields.

**Course Outcomes:**

1. The basics of divisibility and modular arithmetic.
2. And be able to solve congruence problems for degree one and some special cases of degree two, using the Chinese Remainder Theorem.
3. The concept of Legendre and Jacobi symbol, quadratic residues and law of quadratic reciprocity.
4. The different number theoretic functions.
5. The method of solving linear Diophantine equations.
6. The concept of Algebraic number fields, Algebraic integers, Quadratic Fields.

**Course Contents:**

**Unit 1. Divisibility** **[9 Hours]**

1.1 Introduction
1.2 Divisibility
1.3 Primes

**Unit 2. Congruences** **[9 Hours]**

2.1 Congruences
2.2 Solution of Congruences
2.3 The Chinese Remainder Theorem

**Unit 3. Some functions of Number Theory** **[15 Hours]**

3.1 Greatest integer function
3.2 Arithmetic functions
3.3 The Mobius Inversion formula

**Unit 4. Quadratic Reciprocity** **[18 Hours]**

4.1 Quadratic residues
4.2 Quadratic reciprocity
4.3 The Jacobi Symbol

**Unit 5. Diophantine Equations** **[09 Hours]**

5.1 Diophantine equations $ax + by = c$

5.2 Pythagorean triplets.

**Unit 6. Algebraic Numbers** **[30 Hours]**

6.1 Algebraic Numbers

6.2 Algebraic Number Fields

6.3 Algebraic Integers

6.4 Quadratic Fields

**Recommended Books:**

**Niven, H. Zuckerman and H.L. Montgomery**, An Introduction to Theory of Numbers, 5th Edition, John Wiley and Sons. (§1.1- §1.3, §2.1- §2.3, §3.1- §3.3, §4.1 -§4.3, §5.1 and §5.3, §9.1- §9.5)

**Reference Books:**

1. **David M. Burton**, Elementary Number Theory (Second Ed.), Universal Book Stall, New Delhi, 1991.
2. **K.IrelandandM.Rosen**,AClassicalIntroductiontoModernNumberTheory(SecondEdition,Springer)

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## MTS-506(C)MJ & 507(C)MJP : Combinatorics **[ 2T +2P=04 Credits ]**

**Course Objectives:**

1. A student should be able to understand counting methods for arrangements and selections.
2. A student should acquire sufficient competencies to solve problems on Binomial identities, distribution problems etc.
3. Able to explain various counting principles and Binomial Identities.
4. A student should acquirethe knowledge of the Inclusion-Exclusion Principle to solve combinatorial problems.
5. A student should able to use recurrence relation.

**Course Outcomes:**

1. To learn general counting methods for arrangements and selection.
2. Test and validate Binomial identities, distribution problems. Explain various counting principles and Binomial Identities to solve different problems.
3. Students will able to use generating functions and recurrence relations to solve problems.
4. Apply Inclusion-Exclusion Principle to solve combinatorial problems.
5. Understand inclusion-exclusion with Venn diagrams and inclusion – exclusion formula.
6. To learn restricted positions and Rook polynomials.

**Course Contents:**

**Unit 1. General Counting Methods for Arrangements and Selections [20 Hours]**

1.1Two Basic Counting Principles.
1.2 Simple Arrangements and Selections.
1.3 Arrangements and Selections with Repetitions.
1.4 Distributions.
1.5 Binomial Identities

**Unit 2. Generating Functions [20 Hours]**

2.1 Generating Functions Models.
2.2 Calculating Coefficients of Generating Functions.
2.3 Partitions.
2.4 Exponential Generating Functions.
2.5 A Summation Method

**Unit 3. Recurrence Relations [25 Hours]**

3.1 Recurrence Relations Models.
3.2 Divide and Conquer relations
3.3 Solutions of Linear Recurrence Relations.
3.4 Solution of Inhomogeneous Recurrence Relations.
3.5 Solution with Generating Functions

**Unit 4. Inclusion-Exclusion [25 Hours]**

4.1 Counting with Venn Diagrams.
4.2 Inclusion-Exclusion Formula.
4.3 Derangements and Simple Examples
4.4 Restricted Positions and Rook Polynomials.
4.5 Pigeonhole Principle and Examples.

**Recommended Book:**

***Alan Tucker*,**Applied Combinatorics (Sixth Edition), John Wiley & Sons, New York (2012)

Sections: - 5.1-5.5, 6.1-6.5, 7.1-7.5, 8.1-8.3, Appendix-4.

**Reference books:**

1. **V. Krishnamurthy**, Combinatorial, Theory and Applications, East West Press, New Delhi (1989) Scientific, (1996)
2. **Chen Chaun-Chong, Koh Khee-Meng** : Principles and Techniques in Combinatorics (World Scientific)
3. **Kenneth Rosen**: Discrete Mathematics & It's Applications, Tata Mc-Graw Hill
4. **K. D. Joshi**: Foundations of Discrete Mathematics, Wiley

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## MTS-506(D)MJ & 507(D)MJP : Lattice Theory [ 2T +2P=04 Credits ]

**Course Objectives:**

1. To introduce partially ordered sets and their properties.
2. To understand Lattices as algebraic structures
3. Homomorphism between lattices and Boolean algebra.
4. To understand Stone lattices.

**Course Outcomes:**

1. Recall the algebra and ordered properties to understand POSETs and lattices.
2. Understand different types of lattices.
3. ApplyDedekind`s and Birkhoff`scriterias.
4. Analyze Stone lattices.
5. Explain the use of homomorphisms.
6. Create examples and counter-examples of different types of lattices.

**Course Contents:**

**Unit 1. Partially Ordered Sets and Lattices** **[25 Hours]**

1.1 Two definitions of lattices, Hasse diagrams,
1.2 Homomorphism, isotone maps, ideals,
1.3 Congruence relations, congruence lattices,
1.4 The isomorphism theorem, product of lattices, complete lattice, ideal lattice,
1.5 Distributive–modular inequalities and identifies,
1.6 Complements, pseudo-complements
1.7 Boolean lattice of pseudo-complements, join and meet-irreducible elements

**Unit 2. Characterization theorems and representation theorems** **[25 Hours]**

2.1 Dedekind`s modularity criterion Birkhoff`s distributivity criterion,
2.2 Hereditary subsets, rings of sets
2.3 Stone theorems, Nachbin theorem, statements of Hashimoto's theorem.

**Unit 3. Distributive Lattices** **[20 Hours]**

3.1 Distributive lattices with pseudo-complementation,
3.2 Stone lattices, Characterization of stone lattices, Stone Algebra,
3.3 Characterization of Stone Algebra

**Unit 4. Modular Lattices:[20 Hours]**

4.1 Modular lattices, isomorphism theorem,
4.2 Upper and lower covering conditions,
4.3 Kuros-Ore theorem, independent sets.

**Recommended Books:G. Gratzer,** General Lattice Theory, Birkhauser, 2nd Edition 1998.
Section 1.1-1.4, 1.6, 2.1, 2.6, 4.1

**Reference Books:**


1. **Birkhoff, G.**, Lattice Theory, Amer. Math. Soc., Providence, R. I. Vol. 25, Third Edition, 1967.
2. **Blyth, T. S.,** Lattices and Ordered Algebraic Structures, Springer-Verlag, London, 2005.
3. **Davey, B. A. and Priestley, H. A.,** In Introduction to Lattices and Order, Cambridge University Press, Cambridge, 2002.
4. **Stern, M.,**Semimodular Lattices, Theory and Applications, Cambridge University Press, 1999.


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## MTS-508MJ & 509 MJP : Research Methodology [ 2T +2P=04 Credits]

**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, analyzing data, and presenting and writing research findings.

**Course Outcomes:***the student will*

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

## Course Contents:

**Unit 1. Foundations of Research:** **[15 Hours]**

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.

**Unit 2. Research Design:** **[15 Hours]**

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.

**Unit 3. Research Methods:** **[15 Hours]**

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.

**Unit 4. Research Writing and Presentation:** **[15 Hours]**

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,

**Unit 5. Research Ethics and Responsible Conduct:** **[15 Hours]**

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.

**Unit 6. Mathematical Software and Paraphrasing Software:** **[15 Hours]**

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 be done at the college/institute level that includes but is 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 Programme and the expertise of the instructor.

**References:**


- **Kothari, C.R.**(2008), Research Methodology: Methods and Techniques. Second Edition. New Age International Publishers, New Delhi.
- **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.


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# Semester- II

## MTS-551MJ & 552MJP: Topology [2T +2P=04 Credits]

**Course Objectives:**

1. Explore the foundations of mathematics (logic and set theory) at a level and depth appropriate for someone aspiring to study higher-level mathematics and to become a professional mathematician.
2. Understand open sets in general context.
3. Present an introduction to the field of topology, with emphasis on those aspects of the subject that are basic to higher mathematics.
4. Understand Topological properties of a space.

**Course Outcomes:**

1. Understand terms, definitions and theorems related to topological spaces
2. Demonstrate knowledge and understanding of concepts such as open and closed sets, interior, closure and boundary, connectedness, compactness, countability and separation axioms.
3. Create new topological spaces from existing topological spaces.
4. Use continuous functions and homeomorphisms to understand structure of topological spaces
5. Understand difference and interrelationship between Metric Spaces and Topological Spaces.
6. Apply theoretical concepts in topology to understand real world applications.

**Course Contents:**

**Unit 1. Topological Spaces** **[27 Hours]**

1.1 Infinite Sets and Axiom of Choice
1.2 Well Ordered Sets
1.3 Topological Spaces
1.4 Basis for a Topology
1.5 Order Topology
1.6 Product Topology on $X \times Y$
1.7 Subspace Topology

**Unit 2. Continuous Functions** **[18Hours]**

2.1 Closed Sets and Limit Points
2.2 Continuous Functions
2.3 The Product Topology
2.4 Metric Topology

2.5: Metric Topology(continued)

**Unit 3.Connected and Compact Spaces** **[25Hours]**

3.1 Connected spaces
3.2 Connected Subspaces of Real Line
3.3 Components and Local Connectedness
3.3 Compact spaces
3.4 Compact Subspaces of the Real Line
3.5 Limit point compactness
3.6 : Local Compactness

**Unit 4.Countably and Separation Axioms** **[20 Hours]**

4.1 Countability Axioms
4.2 Separation axioms
4.3 Normal Spaces
4.4 Urysohn Lemma
4.5 Tietze Extension Theorem
4.6 The UrysohnMetrization Theorem
4.7 Tychonoff's Theorem

**Recommended Book :J. R. Munkres,** *Topology: A First Course*, ( Pearson Prentice Hall, third Edition), 2007.

Ch1: Sec. 9, 10.
Ch2: Sec.12 to 21.
Ch3: Sec. 23 to 29.
Ch4: Sec. 30 to 35. ( statement with applications) .
Ch5: Sec. 37.

**AdditionalReferences:**


1. **K. D. Joshi**, Introduction to General Topology - (New Age International)
2. **J. L. Kelley.**General Topology - (GTM, Springer,1975)
3. **L. A. Steen and J. A. Seebach**Counterexamples in Topology -. (Springer)
4. **C. Adams and R. Franzosa**Introduction to Topology, Pure, and Applied (Pearson , 2009).


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## MTS-553 MJ : Ring Theory **[04 Credits]**

**Course Objectives:**

1. Understand the basic concepts of Ring theory.
2. Define, Euclidean Domains, Principal Ideal Domains.
3. Define, Unique Factorization Domains:.
4. Understand basic properties of Unique Factorization Domains.
5. Apply Polynomial Ring over fields.

**Course Outcomes:**

1. Students understand the fundamental concept of Rings, Fields, subrings, integral domains and the corresponding Homomorphism's.
2. Students learn in detail about polynomial rings. Matrix ring and group ring.
3. Students are able to determine or classify rings into UFD, PID and ED
4. Understanding the concepts of ring of polynomials and irreducibility tests for polynomials over ring of integers

**Course Contents:**

**Unit 1: Introduction to Rings: [17 Hours]**

1.1 Revision of Basic definition and properties of Rings
1.2 Examples of Rings
1.3 Ring Homomorphism's, Quotient Rings and Ideals
1.4 Properties of ideals
1.5 Rings of Fractions

**Unit 2: Euclidean Domains, Principal Ideal Domains [15 Hours]**

2.1 Euclidean Domains
2.2 Principal Ideal Domains

**Unit 3: Unique Factorization Domains: [10 Hours]**

3.1 Unique Factorization Domains
3.2 Fundamental Theorem of Arithmetic
3.3 Factorization in the Gaussian Integers

**Unit 4: Polynomial Rings: [18 Hours]**

4.1Basic properties of Polynomial Rings
4.2 Polynomial Ring over fields I
4.3Irreducibility Criteria
4.4 Polynomial rings that are Unique Factorization Domain
4.5 Polynomial Ring over fields II

**Recommended Book:** 1. **David S. Dummit, Richard M. Foote,** Abstract Algebra (3rd Edition) John Wiley and Sons

Unit 1: Chapter 7: 7.1 to 7.5 Unit 2: Chapter 8: 8.1 to 8.2

Unit 3: Chapter 8: 8.3 Unit 4: Chapter 9: 9.1 to 9.5

**Reference Books:**

1. **Michael Artin,** Algebra (2nd Edition) Person Education Limited.
2. **C. Musili**,Rings and Modules, 2nd Revised Edition Narosa Publishing House.
3. **Jain and Bhattacharya,**Basic Abstract Algebra, 2nd Edition, Cambridge University Press.
4. **N. Jacobson**, Basic Algebra, Volume 1, Dover publication

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## MTS-554 MJ: Advanced Calculus [04 Credits]

**Course Objectives:**

1. Understand the basic concepts of differential calculus of scalar and vector fields.
2. Apply the chain rule to derivatives of scalar and vector fields.
3. Calculate line integrals and understand their applications.
4. Define and evaluate double integrals.
5. Apply Green's theorem and the change of variables formula to double integrals.
6. Understand the basic concepts of surface integrals

**Course Outcomes:**

1. Be able to define and differentiate scalar and vector fields.
2. Be able to calculate directional derivatives, partial derivatives, and higher-order partial derivatives.
3. Be able to apply the chain rule to derivatives of scalar and vector fields.
4. Be able to calculate line integrals and understand their applications.
5. Be able to define and evaluate double integrals.
6. Be able to apply Green's theorem and the change of variables formula to double integrals.
7. Be able to define and calculate surface integrals.
8. Be able to apply the theorem of Stokes and the divergence theorem.

**Course Contents:**

**Unit 1. Differential Calculus of Scalar and Vector Fields** **[20 Hours]**

1.1 Functionsfrom$R^n$to$R^m$, Scalarandvectorfields,Limitsandcontinuity.

1.2 The derivative of a scalar field with respect to a vector, Directional derivativesand partial derivatives, Partial derivatives of higher order, Inverse functiontheoremand ImplicitFunction theorem.

1.3 Directional derivatives and continuity, The total derivatives, The gradient of ascalarfield, A sufficient condition for differentiability.

1.4 A chain rule for derivatives of scalar fields, Applications to geometry, LevelSets, Tangent planes, Derivatives of vector fields, Differentiability impliesContinuity, The chain rule for derivatives of vector fields, Matrix form of thechainrule.

**Unit 2. Line Integrals** **[10 Hours]**

2.1 Paths and line integrals, other notations for line integrals, Basic properties of lineintegrals.

2.2 The concept of work as a line integral, Line integrals with respect to arc length,further applications of line integrals.

2.3 Open connected sets. Independence of the path, The first and secondfundamental theorem of calculus for line integrals, Necessary and sufficientconditions for a vector field to be a gradient, Necessary conditions for a vectorfieldtobe a gradient.

**Unit 3. Multiple Integrals** **[15 Hours]**

3.1 Partitions of rectangles. Step functions, The double integral of a step function,The definition of the double integral of a function defined and bounded on aRectangle, Upper and lower double integrals, Evaluation of double integral byrepeated one- dimensional integration, Geometric interpretation of the doubleintegralasa volume.

3.2 Inerrability of continuous functions; Inerrability of bounded functions with Discontinuities, Double integrals extended over more general regions,Applicationstoareaandvolume.

3.3 Green's theorem in the plane, Some applications of Green's Theorem, A necessary and sufficient conditionforatwo-dimensionalVector Field tobea gradient.

3.4 Change of variables in a double integral, special cases of the transformationformula with proof, General case of the transformation formula with proof,Extensions to higher dimensions, Change of variablesin an n-fold integral.

**Unit 4. Surface Integrals** **[15 Hours]**

4.1 Parametric representation of a surface, the fundamental vector product, thefundamental vector product as a normal to the surface, Area of a parametricsurface.

4.2 Surface integrals, Change of parametric representation, Other notations forsurfaceintegrals

4.3 The theorem of Stokes, Curl and divergence of a vector field, Properties of curland divergence, the divergence theorem (Gauss' theorem) and applications ofdivergencetheorem.

**Recommended Book:**

1. **Tom M. Apostol,** *Calculus Volume II (Second Edition)*, Indian Reprint 2016 (JohnWiley& Sons,Inc) ISBN: 978-81-265-1520-2.

   Unit1:Chapter8:8.1,8.4,8.6-8.22

   Unit2:Chapter10:10.2to10.11,10.14to10.16

   Unit3:Chapter11:11.2to11.15,11.19to11.22,11.26to11.33

   Unit4:12.1to12.15,12.19,12.20.

2. For"InverseFunctionTheorem"and"ImplicitFunctionTheorem", **TomM.Apostol,** *Mathematical Analysis 2nd Edition* Narosa Publication 20th Reprint2002. ISBN978-81-85015-66-8.

**Reference Books:**


1. **Munkres, J. R.** Analysis on manifolds. Addison-Wesley Publishing Company (1991).
2. **Spivak M.** Calculus on manifolds, Addison-Wes.Publishing Company (1965)
3. **GeraldB.Folland**, AdvancedCalculus, PearsonEdition2012.
4. **ADevinatz**, Advanced Calculus(Holt,Reinhart&Winston) 1968.
5. **James J. Callahan**, Advanced Calculus-A Geometric View, Springer, 2010
6. **David V. Widder**, Advanced Calculus (Second Edition), Dover, 1989
7. **Sudhir R. Ghorpade and Balmohan V. Limaye**, A course in Multivariable Calculus and Analysis , Springer, 2009
8. **Jarold Marsden, Anthony Tromba and Alan Weinstein**, Basic Multivariable Calculus, W H Freeman and Co Ltd, 2001.


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## MTS-555MJP : Data Science [2PCredits]

**Course Objectives:**

1. 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.
2. The course explores the role of data science in the era of big data and provides a strong foundation in statistical analysis and predictive modelling.
3. 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.
4. 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 Outcomes:**

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

**Course Contents:**

**Pre-requisite:**Programming in Python

**Unit 1: Data Science in a big data world:** **[12 Hours]**

1.1 Need, benefits and uses of data science and big data
1.2 Overview of the data science process
1.3 The big data ecosystem and data science
1.4 Challenges in big data world
1.5 Importance of Mathematics and Statistics in data science

**Unit 2: Statistical Foundation for Data Science.** **[18 Hours]**

2.1Analysis of Variance
2.2Data and data representation Techniques
2.3 Measure of Central Tendency and Variability
2.4 Exploratory Data Analysis
2.4 Introduction to probability and probability distributions
2.5 Methods of Estimation
2.6 Testing of Hypothesis.

**Unit 3: Data Pre-processing.** **[15 Hours]**

3.1 Data and data quality
3.2 Missing Value Analysis and Data wrangling
3.3 Label encoding and feature selection
3.4 Data Visualization techniques
3.5 Data integration and reshaping
3.6 Graph mining methods
3.7 Tex mining techniques

**Unit 4: Predictive Modeling.** **[15 Hours]**

**4.1 Supervised Learning.**

4.1.1 Regression Analysis: Linear, Non-linear and correlation

4.1.2. Time Series Analysis: ARIMA, SARIMA, VERMAX

4.1.3. Classification Techniques: Logistic regression, Decision trees, Random forest, Support Vector Machine

**4.2 Unsupervised Learning.**

4.2.1 Clustering: K-means, Hierarchical clustering, density-based clustering

4.2.2 Dimensionality reduction using PCA and t-SNE

4.2.3 Association rules mining

**4.3 Evaluation metrics for Machine Learning models.**

**Note: Lab sessions on different statistical and machine learning techniques covered in Course.** **[60 Hours]**

**Recommended Books:**

1. **Foster Provost and Tom Fawcett,** *Data Science for Business*. O'REILLY publications, 2013.
   Unit 1: Chapter 1 Unit 3: Chapters 6, 7, 8, 10 Unit 4: Chapters 3, 4, 5
2. **Peter Bruce, Andrew Bruce & Peter Gedeck,** *Practical Statistics for Data Scientists*, 2nd Edition.
   Unit 2: Chapters 1, 2, 3, 4 Unit 4: Chapters 5, 6, 7.

**Reference Books:**

1. **Peter Bruce, Andrew Bruce & Peter Gedeck**, Practical Statistics for Data Scientists, 2nd Edition
2. **Jiawei Han, Micheline Kamber & Jian Pei**, Data Mining, Concepts and Techniques, 3rd Edition
3. **Ethem Alpaydin,** Introduction to Machine Learning, Edition 2, The MIT Press.
4. **S. C. Gupta,**Fundamentals of Statistics, Himalaya Publishing House

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## MTS-556(A) MJ & 557 (A) : MJP: Graph Theory [ 2T +2P=04 Credits ]

**Course Objectives:**

1. Students will achieve command of the fundamental definitions and concepts of graph theory.
2. Students will understand and apply the core theorems and algorithms, generating examples as needed, and asking the next natural question.
3. Students will achieve proficiency in writing proofs, including those using basic Graph theory proof techniques such as bijections, minimal counterexamples, and Loaded induction.
4. Students will work on clearly expressing mathematical arguments, in discussions and in their writing.
5. Students will become familiar with the major viewpoints and goals of graph theory: classification, externality, optimization and sharpness, algorithms, and duality.
6. Students will be able to apply their knowledge of graph theory to problems in other areas, possibly demonstrated by a class project.

**Course Outcomes:**

1. Understanding of fundamental concepts: Students should have a strong understanding of the fundamental concepts of graph theory, including vertices, edges, paths, cycles, connectivity, and isomorphism. They should be able to analyze and manipulate graphs using these concepts.
2. Graph Algorithms: Students should be proficient in implementing and analyzing graph algorithms. This includes algorithms for graph traversal (e.g., breadth-first search), shortest paths (e.g., Dijkstra's algorithm), and minimum spanning trees (e.g., Prim's algorithm, Kruskal's algorithm).
3. Graph Theory Applications: Students should be able to apply graph theory concepts and algorithms to solve real-world problems in various domains. This includes applications in computer science, network analysis, social networks, logistics, optimization, and scheduling.
4. Graph Properties and Structures: Students should be familiar with important properties and structures of graphs, such as bipartiteness, Eulerian and Hamiltonian paths and cycles, tree structures, and graph coloring. They should understand the relationships between these properties and be able to apply them to problem-solving.
5. Graph Optimization Problems: Students should be able to formulate graph optimization problems, such as the traveling salesman problem, maximum matching, and graph partitioning. They should understand the complexity of these problems and be able to design and analyze efficient algorithms to solve them..
6. Advanced Topics in Graph Theory: Students should be exposed to advanced topics in graph theory, including graph embedding, spectral graph theory, random graphs, graph

minors, and algorithmic graph theory. They should be able to explore and understand research papers in these areas.

7. Research Skills: Students should develop research skills, including literature review, identifying research gaps, formulating research questions, and designing experiments or theoretical investigations. They should be able to contribute to the field of graph theory through independent research or project work.
8. Overall, the course aims to equip postgraduate students with a comprehensive understanding of graph theory, its applications, and its theoretical foundations. It prepares them for further research in graph theory or related areas, as well as for careers in fields such as computer science, data analysis, network analysis, operations research, and optimization.

**Course Contents:**

**Unit 1:An Introduction to Graphs: [20 Hours]**

The Definition of a Graph, Graphs as Models, More Definitions, Vertex Degrees, Subgraphs, Paths and Cycles, Matrix Representation of Graphs, Fusion.

**Unit 2:Trees and Connectivity: [15 Hours]**

Definitions and Simple Properties, Bridges, Spanning Trees, Connector Problems, Shortest Path Problems, Cut Vertices and Connectivity.

**Unit 3:Euler Tours and Hamiltonian Cycles: [15 Hours]**

Euler Tours, The Chinese Postman Problem, Hamiltonian Graphs, The Travelling Salesman Problem.

**Unit 4:Matchings: [15 Hours]**

Matching and augmenting paths, Hall's Marriage Theorem, The Personnel Assignment Problem.

**Unit 5:Colouring: [15 Hours]**

Vertex colouring, Vertex colouring algorithms, Critical graphs, Cliques, Edge colouring.

**Unit 6:Directed Graphs:** Definitions, In degree and Out degree. **[10 Hours]**

**Recommended Book :John Clark and D. A. Holton**, *A First Look at Graph Theory*, World Scientific (1995).

Unit 1: 1.1-1.8Unit2: 2.1-2.6Unit 3: 3.1-3.4

Unit4: 4.1-4.4Unit. 5: 6.1-6.5 Unit. 6: 7.1-7.2

**References:** 1. **Harary,** Graph Theory, Narosa Publishers (1989).

2. **Nora Hartsfield and Gerhard Ringel**, Pearls Theory, Academic Press (1990).
3. **Narsingh Deo**, Graph Theory with applications to computer science and engineering, Prentice Hall (2009).

4**. Douglas B. West**, Introduction to Graph Theory, Prentice- Hall (1999).

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## MTS-556(B) MJ & 557 (B): Dynamical Systems **[ 2T +2P=04 Credits ]**

**Course Objectives:**

1. Students able to find solution system of linear differential equations.
2. Students able to draw phase portrait of dynamical systems in two dependent variables.
3. Students able to find equilibrium points and identify nature of phase portrait in neighbourhood of the equilibrium point.
4. Students able to decompose the phase portrait into stable, unstable, centre manifold.
5. Students able to find normal forms of dynamical systems.
6. Students able to find bifurcation of one dimensional maps.

**Course Outcomes:**

1. Explain the behavior of the systems of differential equations.
2. Implement techniques to describe the behaviour of dynamical systems.
3. Differentiate the nature of dynamical systems.
4. Judge the technique to solve and behaviour of dynamical systems.
5. Develop criteria to solve and discuss the nature of dynamical systems.

**Course Contents:**

**Unit 1**: **Linear System of Differential Equations:** **[15 Hours]**

1.1 Introduction to system of differential equations.
1.2 Fundamental set of solutions.
1.3 Solutions and phase portraits of linear homogeneous system with constant coefficients
1.4 Non homogeneous systems with time-dependent forcing.

**Unit 2:Flow of Nonlinear system of Differential Equations:** **[10 Hours]**

2.1 Solutions of nonlinear systems of differential equations.
2.3 Existance and uniqueness of solution.
2.4 Gronwall inequality.

**Unit 3: Fixed Points and Stability of Differential System:** **[15 Hours]**

3.1 Limit sets.
3.2 Stability of fixed Points.
3.3 Stability and fixed points of one dimensional equation.
3.4 Nullclines for planar systems.
3.5 Linearization and stability.
3.6 Competitive Population model.

**Unit 4: Phase Portraits Using Scalar Functions:** **[20 Hours]**

4.1 Predator-Prey Systems
4.2 Systems with undamped forces
4.3 Lyapunov functions

4.4 Bounding functions

4.5 Gradient systems.

**Unit 5: Periodic Orbits and Bifurcations: [18 Hours]**

5.1 Introduction to periodic orbits, limit cycles, Poincare map.
5.2 Poincaré-Bendixson theorem.
5.3 Self-Excited oscillator.
5.4 Andronov-Hopf bifurcation.
5.5 Homoclinic bifurcation.
5.6 Poincaré map.

**Unit 6:Introduction to Discrete Dynamical Systems: [12 Hours]**

6.1 One dimensional maps

6.2 Periodic points of one dimensional maps

6.3 Iteration Using the Graph

6.4 Stability of Periodic Points.

**Recommended Book:R. Clark Robinson**, *An Introduction to Dynamical Systems-Continuous and Discrete*, (Second Edition), American Mathematical Society (AMS), 2012.

**Section**: 2.1-2.5, 3.1-3.3, 4.1-4.8, 5.1-5.7, 6.1-6.9, 8.1, and 9.1-9.3.

**Reference Books:**

1. **Lawrence Perko,**Differential Equations and Dynamical Systems (Third Edition), Springer, 2001.
2. **James D. Meiss**, Differential Dynamical Systems, Society for Industrial and Applied Mathematics (SIAM), 2007.
3. **Steven H. Strogatz**, Nonlinear Dynamics and Chaos- With Applications to Physics, Biology, Chemistry, and Engineering, CRC Press, 2015.
4. **Morris W. Hirsch, Stephen Smale, Robert L. Devaney**, Differential Equations, Dynamical Systems, and an Introduction to Chaos, (Third Edition), Elsevier, 2016.
5. **Stephen Lynch**, Dynamical Systems with Applications using Python, Birkhauser, 2018.
6. **Fritz Colonius, Wolfgang Kliemann**, Dynamical Systems and Linear Algebra, American Mathematical Society (AMS), 2014.

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## MTS-556(C) MJ & 557 (C): Coding Theory **[ 2T +2P=04 Credits ]**

**Course Objectives:**

1. To understand the role and significance of information and coding theory in theory and practice.
2. To understand how theory of finite fields and linear algebra comes to applied in designing of codes.
3. To understand different techniques of error detection and correction.
4. To understand applications of coding theory.

**Course Outcomes:** *The student will have to*

1. Understand the need for encoding and decoding strategies and the concept of error correction.
2. Understand how finite fields and linear algebra can be used to construct codes.
3. Understand the significance various bounds in coding theory .
4. Learn some applications of coding theory.

**Course Contents:**

**Unit I: Error detection, correction and decoding**: **[18 Hours]**

Communication channels, Maximum likelihood decoding, Hamming distance, Nearest neighbor / minimum distance decoding, Distance of a code.

**Unit II: Finite Fields:** **[7 Hours]**

Basics of finite fields, construction of finite field as quotient of polynomial ring, minimal polynomials.

**Unit III: Linear codes:** **[30 Hours]**

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, Cosets, Nearest neighbor decoding for linear codes.

**Unit IV: Bounds in Coding Theory: [20 Hours]**

Main Coding theory problem, lower bound, sphere covering bound, Hamming bound and perfect codes, Binary hamming codes**,** Singleton bound and MDS codes.

**Unit V: Cyclic codes:** **[15 Hours]**

Definitions, Generator polynomials, Generator and parity check matrices, Decoding of cyclic codes.

**Recommended Book:San Ling and ChaoingXing**,*Coding Theory- A First Course.* Cambridge University Press :Unit-1:2.1, 2.2, 2.3, 2.4, 2.5Unit-2:3.1,3.2, 3.3,3.4

Unit-3 :4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8Unit-4: 5.1, 5.2, 5.3, 5.4

Unit-5: 7.1, 7.2, 7.3, 7.4

**Reference Books:** 1.**Raymond Hill**, A First Course in Coding Theory (Oxford)

2. **J. H. van Lint**, An Introduction to Coding Theory (Springer, Third Edition)

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## MTS-556(D) MJ & 557 (D): Operations Research [2T +2P=04 Credits]

**Course Objectives:**

1. To identify the concept of Linear Programming Problem.
2. To apply methods to solve Integer Programming problems and analysis of the solutions.
3. To understand the effect of variations in input data through sensitivity analysis.
4. To analyze the primal-dual relationship of a linear Programming problem and compute the dual.
5. To understand concept of multi-objective optimization problem by Goal Programming Approach.
6. To understand the concept of Non-linear Programming and methods of solving the Nonlinear Programming problems.

**Course Outcomes:**

1. The successful completion of this course students will able to Formulate real life problems into linear Programming problem.
2. Understand the importance of sensitivity analysis in managerial decision making.
3. Analyze the effect of variations in input data of linear Programming problem through sensitivity analysis.
4. Understand the importance of duality in linear Programming problem.
5. Understand the concept of multi-objective decision problems.
6. Use the quadratic Programming models for real life problems.

**Course Contents:**

**Unit I: Linear Programming Problem [18 Hours]**

1.1 Standard form of Linear Programming Problem.

1.2 Simplex method

1.3 Big-M method

1.4 Types of linear Programming solutions

1.5 Duality in linear Programming problem

a) Primal-Dual Relationship

b) Economic interpretation of dual variables and constraints

c) Managerial significance of duality d) Solution of primal linear Programming problem using dual linearProgramming problem

**Unit II: Sensitivity Analysis in Linear Programming[18 Hours]**

2.1 Changes in objective function coefficients

2.2 Changes in availability and resources

2.3 Changes in the input-output coefficients

**Unit III: Integer Linear Programming[18 Hours]**

3.1 Types of Integer Programming Problems

3.2 Gomory’s all integer cutting plane method

3.3 Gomory’s mixed- integer cutting plane method 3.4 Branch and Bound Method.

**Unit 4: Goal Programming [18Hours]**

4.1 Difference between linear Programming and goal Programming

4.2 Concept of Goal Programming

4.3 Goal Programming Model Formulation

4.4 Graphical solution method for Goal Programming

4.5 Modified Simplex method of Goal Programming

**Unit 5: Non-Linear Programming Problem [18 Hours]**

5.1 The general non-linear Programming problem

5.2 Graphical solution method

5.3 Quadratic Programming

a) Kuhn-Tucker Conditions b) Wolfe’s Modified Simplex Method c) Beale’s Method

**Recommended Book: J. K. Sharma**, *Operations Research*, (Third Edition, Macmillan India Ltd.),2008.

Chapter 4: 4.1, 4.2, 4.3, 4.4.2, 4.5, 4.6 Chapter 5: 5.1, 5.2, 5.3, 5.4, 5.5

Chapter 6: 6.1, 6.2.1, 6.2.2, 6.2.3 Chapter 7: 7.1, 7.2, 7.3, 7.4, 7.5, 7.6

Chapter 8: 8.1, 8.2, 8.3, 8.4, 8.5, 8.6 Chapter 24: 24.1,24.2, 24.3, 24.4, 24.5

**Reference Books:**

1. **Hamdy A. Taha**, Operations Research, (Eighth Edition, Prentice Hall of India), 2008.

2**. P. K. Gupta and D. S. Hira,** Operations Research, (Fifth Edition, S. Chand), 2014.

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## MTS-558 :On Job Training (OJT)/ Field Project [04 Credits = 120 Hrs]

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 prerequisite for OJT. The course will be conducted as per the guidelines of the Institute /the University and Government of Maharashtra.

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