



**R.E. Society's
R.P. Gogate College of Arts & Science
and R.V. Jogalekar College of
Commerce, Ratnagiri (Autonomous)**

**Master of Science (M.Sc.)
Mathematics
Two Years Integrated Programme
Under Choice Based Credit System (CBCS)**

**Syllabus for M.Sc. Semester III and IV
To be implemented from Academic Year-
2023-2024**

Format for Submission of Curriculum to BOS

Name of Programme	M.Sc. Mathematics
Level	PG
No of Semesters	04
Year of Implementation	2023-24
Programme Specific Outcomes (PSO)	<ol style="list-style-type: none">1) Students demonstrate an understanding of commonly used facts, formulae, terminology, and definitions. Students can write well-constructed and logical mathematical proofs.2) Students will get advanced knowledge of principles, methods and clear perception of innumerable power of mathematical ideas and tools.3) Student will get knowledge about both pure as well as applied mathematics branches
Relevance of PSOs to the local, regional, national, and global developmental needs	<p>The study of M.Sc mathematics helps to</p> <ol style="list-style-type: none">1) inculcate critical thinking to carry out scientific investigation objectively without being biased, prepare students for pursuing research or careers in industry in mathematical sciences.2) Create awareness to become an enlightened citizen with commitment to deliver one's responsibilities3) To create Ability to evaluate the reliability and relevance of evidence; identify logical flaws and holes in the arguments of others; analyze and synthesize data from a variety of sources4) Enhance Capability for mapping out the tasks of a team or an organization, and setting direction, formulating an inspiring vision, building a team who can help achieve the vision, motivating and inspiring team members to engage with that vision, and using management skills to guide people to the right destination in a smooth and efficient way.

Note: 1) For semester III, the 2 elective papers should be selected from following 3 papers-

- 1) Numerical Analysis
- 2) Graph theory
- 3) Algebraic Number Theory

2) For semester IV, 1 Skill based course should be selected from following 2 papers-

- 1) Linear and nonlinear programming
- 2) Computational algebra

Master of Science (M.Sc) Programme
Under Choice Based Credit System (CBCS)
Course Structure

M.Sc II Subject- Mathematics
(To be implemented from Academic Year 2023-24)

M.Sc I Subject- Mathematics

Course code	Semester III	Credits	Course code	Semester IV	Credits
PSMT301	Algebra III	6	PSMT401	Algebra IV	6
PSMT302	Functional Analysis	6	PSMT402	Fourier Analysis	5
PSMT303	Differential Geometry	6	PSMT403	Calculus on Manifolds	5
PSMT304	Elective 1- (Numerical Analysis)	3	PSMT404 OR PSMT405	Skill Based course (Linear and nonlinear programming Or Computational algebra)	4
PSMT305	Elective 2 – (Graph theory)	3	PSMT406	Project	4
PSMT306	Elective 3- (Algebraic Number Theory)	3			
Total Credits		24	Total Credits		24

Teaching pattern for theory courses –

1. Four lectures per week for the per course.
2. Each lecture will be of 60 minutes.

Revised syllabus of courses of Master in Science II (M.Sc II) - semester III with effect from academic year 2023-24

Course Code	Semester III	Credits
PSMT301	Algebra III	6
PSMT302	Functional Analysis	6
PSMT303	Differential Geometry	6
PSMT304	Elective 1- (Numerical Analysis)	3
PSMT305	Elective 2 – (Graph theory)	3
Total Credits		24

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Algebra III
Course Code	PSMT301
Class	M. Sc. II
Semester	III
No of Credits	05
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	Group theory has many applications in daily life, particularly in the fields of mathematics, physics, chemistry, and computer science. For example, group theory is used in cryptography to create secure communication systems, in quantum mechanics to understand the behavior of subatomic particles, in crystallography to study the structure of crystals, and in computer graphics to create 3D animations. Additionally, group theory has applications in music theory and art, as it can be used to describe symmetries and patterns in compositions and designs. Ring theory has applications in number theory and geometry.

Nomenclature: algebra III

Course Outcomes:

- CO1 : Students will learn about classical groups like Simple groups, Solvable groups and Nilpotent groups and applications of these classical groups.
- CO2 : Motive of an introduction of the Zariski topology is to take a glance at algebraic geometry which is like the ocean in its own right. This topic provides a geometric point of view of algebra. It gives students a wider perspective to rethink the nature of a prime ideal, maximal ideal and very precisely the geometric position of prime and maximal ideals. It also helps to visualize the radical of an ideal in a geometric setting and the local nature of a prime ideal.
- CO3 : Students will learn Finitely generated modules, Free modules, Free modules of rank n .
- CO4 : Students will understand the Structure theorem for finitely generated modules over a PID and Applications to the Structure theorem for finitely generated Abelian groups and linear operators.

Unit No.	Units	No. of lectures
1	Groups	15
2	Rings and Ideals	15
3	Modules	15
4	Modules over PID	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Groups	1.1 : Simple groups, Solvable groups. 1.2 : Zassenhaus Lemma, Jordan-Holder theorem. 1.3 : The group of affine transformations . 1.4 : Dihedral group D_{2n} as semi-direct product.	15
II	Rings and Ideals	2.1 : Nilradical and relation to prime ideals. 2.2 : Jacobson radical and maximal ideals. 2.3 : Annihilator ideal . 2.4 : Hilbert Nullstellensatz .	15
III	Modules	3.1 : Modules, Submodules, kernels, Quotient modules. 3.2 : Generation of modules. 3.3 : Free modules. 3.4 : Dimension of a free module over a P.I.D.	15
IV	Modules over PID	4.1 : Noetherian modules and equivalent conditions. 4.2 : Torsion free Modules, Submodules. 4.3 : Finitely generated modules over a PID. 4.4 : Structure theorem for finitely generated modules over a PID.	15

Learning Resources recommended:

1. M. Artin, Algebra, Prentice Hall of India, 2011.
2. D. S. Dummit and R. M. Foote, Abstract Algebra.
3. N. Jacobson, Basic Algebra, Volume 1, Dover, 1985.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Functional Analysis
Course Code	PSMT302
Class	M.Sc II
Semester	III
No of Credits	6
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	Functional analysis is a branch of mathematical analysis that studies vector spaces with a limit structure (such as a norm or inner product), and functions or operators defined on these spaces. Functional analysis provides a useful framework and abstract approach for some applied problems in a variety of disciplines. Functional analysis plays an important role in the applied sciences as well as in mathematics itself.

Nomenclature: Functional Analysis

Course Outcomes:

CO1: Students will learn Hilbert spaces and Banach spaces.

CO2: Students will be able to understand the concept of dimension of a Hilbert space, bounded linear transformations, norms, inner products, dual spaces and their difference from the finite dimensional cases.

CO3: Students will know about spaces, dual spaces and their properties.

CO4: Students will understand the Hahn Banach theorem, its application, Open mapping theorem, closed graph theorem, Uniform boundedness principle and its application.

Unit No.	Units	No. of lectures
1	Baires spaces and Hilbert spaces	15
2	Normed Linear Spaces	15
3	Bounded Linear Transformations	15
4	Basic Theorems	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
1	Baires spaces and Hilbert spaces	1.1 Baire spaces, Hilbert Spaces, Inner product induced by norm, Bessel's Inequality.	15

		1.2 orthogonal decomposition, Parseval's identity.	
2	Normed Linear Spaces	2.1 Normed Linear spaces, Banach spaces 2.2 Holder's inequality, Minkowski's Inequality 2.3 Quotient Space of a normed linear space. 2.4 Equivalent Norms, Riesz Lemma and application to infinite dimensional normed linear spaces.	15
3	Bounded Linear Transformations	3.1 Bounded linear transformations, Equivalent characterizations. 3.2 Dual Space Of a Normed Linear Space, Riesz Representation theorem for Hilbert spaces. 3.3 Separable spaces, examples of separable spaces	15
4	Basic Theorems	4.1 Hahn-Banach Theorem (Extension and Separation), applications of it. 4.2 Open mapping theorem, Closed graph theorem 4.3 Uniform Boundedness Principle And application.	15

Learning Resources recommended:

1. Andrew Browder, Mathematical Analysis, An Introduction, Springer International Edition, 1996.
2. E.Keryszig, Introductory Functional Analysis with Applications, Wiely India, 1978.
3. B.V.Limaye, Functional Analysis, New Age International, 1996.
4. J.R.Munkres, Topology, Prentice Hall, 2000.
5. M.T.Nair, Functional Analysis, Prentice Hall, India
6. H.L.Royden, Real Analysis, Pearson, 4th edition, 2017.
7. G.F.Simmons, Introduction to Topology and Modern Analysis, TataMcGraw-Hill, 2004.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Differential Geometry
Course Code	PSMT303
Class	M.Sc II
Semester	III
No of Credits	6
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	Differential geometry also plays an important part in both classical and modern theoretical physics. Understanding the curvature is essential for the positioning of satellites into orbit around the earth. Differential geometry has many applications in Computer graphics, Robotics, Medical imaging, Control systems. The curvature is of utmost significance in designing road curves and grinding workpieces. While designing road curves, its influence on road safety needs to be considered. In order to improve the efficiency without excessive wear, its influence on the size of grinding wheel requires to be considered. Mobius strips have been used as conveyor belts, fabric computer printer and typewriter ribbons. Medals often have a neck ribbon configured as a Mobius strip that allows the ribbon to fit comfortably around the neck while the medal lies flat on the chest. so study of differential geometry is very useful.

Nomenclature: Differential Geometry

Course Outcomes:

- CO1 - Students will be able to understand types of isometries of Euclidean space and its properties.
- CO2 - Students will be able to grasp parametrization of curves and surfaces.
- CO3- Students will be able to understand the various geometrical aspects like tangent, arc length, curvature, torsion etc of plane and space curves.
- CO4 - Students will be able to understand the role of first fundamental theorem and second fundamental theorem in the computation of Gaussian curvature, mean curvature and principal curvature, properties of various special types of curves and surfaces.

Unit No.	Units	No. of lectures
1	Isometries of Euclidean space	15
2	Curves	15

3	Regular Surface	15
4	Curvature	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
1	Isometries of Euclidean space	1.1 Orthogonal transformations, Reflection, Rotations and Translations. 1.2 Hyper-planes, 1.3 Orientation Preserving And Reversing Isometries. 1.4 Glide reflection.	15
2	Curves	2.1 Parametrized Curves,Regular Curves 2.2 Curvature and torsion of curves, Signed curvature for plane curves 2.3 Fundamental theorem for plane curves 2.4 Serret-Frenet Equations, Fundamental Theorem for space curve.	15
3	Regular Surface	3.1 Regular surfaces, Examples. Tangent Space To A Surface, Differential of smooth function 3.2 Orientable surfaces. The Mobius band is not orientable.	15
4	Curvature	4.1 first fundamental form, Isometries Of Surface, The Gauss map, The shape operator of a surface. 4.2 second fundamental form, Normal Curvature,Principal Curvatures. 4.3 Euler's formula, Meusnier's Theorem,Gaussian Curvature And Mean Curvature 4.4 Geodesics.	15

Learning Resources recommended:

1. M.Artin, Algebra, Prentice Hall of India,2011.

2. C.Bar,Elementary Differential geometry,Cambridge University Press,2010.
3. M.DoCarmo, Differential geometry of curves and surfaces,Prentice Hall Inc.,1976.
4. S.Kumaresan, LinearAlgebra, A Geometric Approach,2000.
5. A.Pressley, Elementary Differential Geometry,Springer UTM.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Numerical Analysis
Course Code	PSMT304
Class	M.Sc. II
Semester	III
No of Credits	03
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	Numerical analysis, area of mathematics and computer science that creates, analyzes, and implements algorithms for obtaining numerical solutions to problems involving continuous variables. Such problems arise throughout the natural sciences, social sciences, engineering, medicine, and business. Since the mid 20th century, the growth in power and availability of digital computers has led to an increasing use of realistic mathematical models in science and engineering, and numerical analysis of increasing sophistication is needed to solve these more detailed models of the world. Numerical analysis is concerned with all aspects of the numerical solution of a problem, from the theoretical development and understanding of numerical methods to their practical implementation as reliable and efficient computer programs.

Nomenclature: Numerical Analysis

Course Outcomes:

- CO1: Students will be able to grasp the concept of numerical solution of various mathematical problems and corresponding errors.
- CO2: Students will be able to understand the approximation of functions by least square method.
- CO3: Students will be aware about applications of various numerical techniques in the solution of difference equations, ordinary and partial differential equations.

Unit No.	Units	No. of lectures
1	Approximation of functions	15
2	Differential and Difference	15

	Equations	
3	Numerical Integration	15
4	Numerical Solutions of Partial Differential Equations	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Approximation of functions	1.1 Least Square approximation: weighted and Chebychev polynomial 1.2 Gram - Schmidt Orthogonalization process 1.3 Fourier Transform: Discrete, Fast	15
II	Differential and Difference Equations	2.1 Difference Equation 2.1.1 Solution of D. E. with constant coefficient by Predictor corrector method & Milne's Method 2.1.2 Linear Boundary Value Problem: Galerkin's Method 2.2 Difference equations 2.2.1 Linear difference equations with constant coefficients 2.2.2 Methods of solving linear difference equations with constant coefficients	15
III	Numerical Integration	3.1 Trapezoidal Rule 3.2 Simpson's 1/3 rd Rule, Simpson's 3/8 th Rule 3.3 Boole's and Weddle's Rule 3.4 Gauss Legendre Numerical Integration 3.5 Gauss - Chebyshev numerical integration 3.6 Gauss - Hermite numerical integration 3.7 Gauss - Laguree numerical integration 3.8 Romberg's method	15

		3.9 Gaussian Quadrature 3.10 Multiple integrals	
IV	Numerical Solutions of Partial Differential Equations	4.1 Classification of partial differential equations 4.2 Finite difference approximation to derivatives 4.3 Numerical methods of solving elliptic, parabolic and hyperbolic equations	15

Learning Resources recommended:

1. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and sons, 2008.
2. Jain, Iyengar, Numerical Methods for Scientific and Engineering Problems, NewAge International, 2009.
3. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley John Wiley & Sons, 1999.
4. S.S. Sastry, Introductory Methods of Numerical Analysis, Prentice-Hall, India, 2012.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars / viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12

5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Graph Theory
Course Code	PSMT305
Class	M.Sc. II
Semester	III
No of Credits	05
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	Graph theory is used to find the shortest path in a road or a network. In google maps, various locations are represented as vertices or nodes and the roads are represented as edges and graph theory is used to find the shortest path between two nodes. In the real world, graph theory is used in the internet field, social media, web page searching, city planning, traffic control, transportation and navigation, traveling salesman problems, GSM mobile phone networks, map coloring, time table scheduling, etc. Graph theory is also used in sociology. After learning Graph Theory an individual can work as a tutor, data analyst.

Nomenclature: graph theory

Course Outcomes:

CO1 : Students will be able to define the basic concepts of graphs, directed graphs, and weighted graphs.

CO2 : Students will be able to define a graph, identifying edges and vertices. finds the degree of a vertex.

CO3 : Students will be able to understand and apply the fundamental concepts in graph theory.

Unit No.	Units	No. of lectures
1	Connectivity	15
2	Trees	15
3	Eulerian and Hamiltonian Graphs	15
4	Matching and Ramsey Theory	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Connectivity	1.1 Overview of Graph theory- 1.2 Friendship Theorem, Components, Isomorphism 1.3 Dijkstra's algorithm, Vertex and Edge connectivity. 1.4 Menger's theorem.	15
II	Trees	2.1 Characterizations of Trees 2.2 Cayley's formula 2.3 Kruskal's algorithm, Huffman coding 2.4 Searching algorithms-BFS and DFS algorithms.	15
III	Eulerian and Hamiltonian Graphs	3.1 Characterization of Eulerian Graph 3.2 Fleury's algorithm, Hamiltonian graphs- Necessary condition. 3.3 Hamiltonian closure of a graph, Chvatal theorem. 3.4 Traveling salesman problem.	15
IV	Matching and Ramsey Theory	4.1 Matchings-augmenting path 4.2 Matching in bipartite graph 4.3 Halls theorem, Konig's theorem, Tutte's theorem. 4.4 Ramsey theorem-Existence of $r(k;l)$. 4.5 Graph Ramsey theorem	15

Learning Resources recommended:

1. J. A. Bondy and U.S. R. Murty, Graph Theory, GTM 244 Springer, 2008.
2. Rosen, Discrete Mathematics and its Applications, Tata-McGraw Hill, 2011.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Algebraic Number Theory
Course Code	PSMT306
Class	M.Sc. II
Semester	III
No of Credits	05
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	Algebraic number theory is a branch of number theory that uses the techniques of abstract algebra to study the integers, rational numbers, and their generalizations. Number-theoretic questions are expressed in terms of properties of algebraic objects such as algebraic number fields and their rings of integers, finite fields, and function fields. These properties, such as whether a ring admits unique factorization, the behavior of ideals, and the Galois groups of fields, can resolve questions of primary importance in number theory, like the existence of solutions to Diophantine equations

Nomenclature: Algebraic Number Theory

Course Outcomes:

CO1: Students will learn about algebraic numbers, algebraic integers and further properties of rings of integers.

CO2: Students will understand the class group.

CO3. Students will gain knowledge of Ramification theory and Diophantine equations

Unit No.	Units	No. of lectures
1	Algebraic Numbers and algebraic integers	15
2	Rings of integers	15

3	Class group	15
4	Ramification theory and Diophantine equations	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Algebraic Numbers and algebraic integers	Number fields, Algebraic numbers, Integral extensions, Ring of integers in a number field, Quadratic fields, Real and imaginary quadratic fields, Ring of integers in a quadratic field, Examples like the ring of Gaussian integers.	15
II	Rings of integers	Norms and traces, basis for the ring of algebraic integers, Norm of an ideal, prime factorization of ideals, Norm of a principal ideal, Definition of Dedekind domain, Fractional ideals, Existence and uniqueness of factorization	15
III	Class group	Principal fractional ideals, Norm map is multiplicative on integral ideals, Minkowski lemma, Finiteness of the class group, Explicit example of factorization in quadratic number fields, Legendre symbol, Jacobi symbol and quadratic reciprocity.	15
IV	Ramification theory and Diophantine equations	Ramification, residue degree, transitivity of ramification and residue degrees, Proof of ramification theorem, Examples, Group of units, Applications to Diophantine equations.	15

Learning Resources recommended:

1. M. Artin, Algebra, Prentice-Hall, India, 2000.
2. S. R. Ghorpade, Lectures on Field Theory and Ramification Theory, IITB.

3. Marcus, Number Fields, Springer.
4. Niven and Zuckermann, An Introduction to the Theory of Numbers, 1980.
5. Algebraic Number Theory, T.I.F.R. Lecture Notes, 1966 10

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Revised syllabus of courses of Master in Science II (M.Sc II) - semester IV with effect from academic year 2023-24

Course Code	Semester IV	Credits
PSMT401	Algebra IV	6
PSMT402	Fourier Analysis	5
PSMT403	Calculus on Manifolds	5
PSMT404	Skill Based course(Linear and nonlinear programming)	4
PSMT406	Project	4
Total Credits		24

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Algebra IV
Course Code	PSMT401
Class	M. Sc. II
Semester	IV
No of Credits	05
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	Galois theory is an important tool for studying the arithmetic of "number fields" and "function fields". The idea of using algebra to bear on geometry problems, and vice-versa, is very beautiful and powerful

Nomenclature: Algebra IV

Course Outcomes:

- CO1 : Students will learn about algebraic extensions and their properties. Splitting fields and their degrees can be computed. The notion of normal extension is introduced and its equivalent properties are discussed.
- CO2 : Students will be able to learn Finite fields as splitting fields are visualized and the notion of algebraic closure is discussed in detail.
- CO3 : Students will be able to learn Galois extensions are studied and the fundamental theorem of Galois theory is established.
- CO4 : Students will be able to learn Cyclotomic extensions are studied in detail and order of its Galois group is computed. Examples of fixed fields, field automorphisms and fundamental theorem are studied in special cases.

Unit No.	Units	No. of lectures
1	Algebraic Extensions	15
2	Normal and Separable Extensions	15
3	Galois Theory	15
4	Applications	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Algebraic Extensions	1.1 : Prime subfield of a field 1.2 : Field extension, Algebraic extensions, Finite extensions. 1.3 : Classical Straight-edge and Compass constructions. 1.4 : Impossibility of the classical Greek problems	15
II	Normal and Separable Extensions	2.1 : Algebraic closure of a field 2.2 : Splitting field for a set of polynomials 2.3 : Perfect Fields. 2.4 : Primitive element theorem. 2.5 : Frobenius automorphism of a finite field	15
III	Galois Theory	3.1 : Galois group $G(K/F)$ of a field extension K/F . 3.2 : Galois extensions. 3.3 : Subgroups, Fixed fields. 3.4 : Fundamental theorem of Galois theory.	15
IV	Applications	4.1 : Cyclotomic field $Q(\zeta_n)$ 4.2 : Cyclotomic polynomial 4.3 : Galois group for an irreducible quartic polynomial. 4.4 : Galois group and Abel's theorem on the insolvability	15

		of a general quintic polynomial.	
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Learning Resources recommended:

1. M. Artin, Algebra, Prentice Hall of India, 2011.
2. D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley and Sons, 2011.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	FourierAnalysis
Course Code	PSMT402
Class	M.Sc II
Semester	4
No of Credits	6
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	Fourier analysis is used in designing electrical circuits, solving differential equations, signal processing, signal analysis, image processing & filtering. Advanced noise cancellation and cell phone network technology uses Fourier series where digital filtering is used to minimize noise and bandwidth demands respectively. It turns out that (almost) any kind of a wave can be written as a sum of sines and cosines. Most audio and image CODECs (including JPEG and mp3) actually use DCTs, which are a subset of generalized Fourier transforms. Signal Processing is the best application of Fourier analysis.

Nomenclature: Fourier Analysis

Course Outcomes:

CO1: Students will be able to understand the Fourier series expansion of a periodic function and their convergence.

CO2: Students will be able to grasp properties of the Dirichlet kernel, Fejer kernel, Poisson kernel and the concept of a good kernel.

CO3: Students will be aware about application of a Fourier series in the solution of the Dirichlet problem and heat equation.

Unit No.	Units	No. of lectures
1	Fourier Series	15
2	Dirichlet's theorem	15
3	Fejer Theorem and applications	15
4	Dirichlet Problem In The Unit Disc	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
1	Fourier Series	1.1 Bessel's Inequality Dirichlet kernel, Convergence theorem for the Fourier series 1.2 Uniqueness theorem, Integrals and Uniform Convergence Properties 1.3 Even And Odd Extensions, Fourier series of a periodic function of an arbitrary period.	15
2	Dirichlet's theorem	2.1 Fourier Coefficient Of Integrable and square integrable periodic functions 2.2 The Riemann-Lebesgue lemma and its converse, Bessel's inequality for a L^2 periodic functions, 2.3 Dirichlet's theorem, Concept of Good kernels, Dirichlet's kernel is not good kernel.	15
3	Fejer Theorem and applications	3.1 Cesaro summability, Cesaro mean and Cesaro sum of the Fourier Series 3.2 Fejer's Kernel, Fejer's kernel is a good kernel,	15

		<p>Fejer Theorem, Parseval's Identity. Convergence of Fourier series of an L^2 periodic functions are the L^2-norm, Riesz-Fischer theorem.</p> <p>3.3 Unitary isomorphism from L^2 onto the sequence space of square summable complex sequences.</p>	
4	Dirichlet Problem In The Unit Disc	<p>4.1 Abel Summability, Abel sum of the Fourier Series, The Poisson kernel, The Poisson kernel is a good kernel.</p> <p>4.2 Laplacian, Harmonic Functions, Dirichlet Problem For The Unit Disc, The solution of the Dirichlet problem for the unit disc. The Poisson integral,</p> <p>4.3 Applications of Fourier Series To Heat Equation On The Circle.</p>	15

Learning Resources recommended:

1. R.Beals, Analysis An Introduction, Cambridge University Press, 2004
2. R.Bhatia, Fourier Series, MAA Press AMS, 2005.
3. G.B.Folland, Fourier Analysis and its Applications, American Mathematical Society, Indian Edition 2010.
4. E.M.Stein and R.Shakarchi, Fourier Analysis an Introduction, Princeton University Press, 2003.
5. E.M.Stein and R.Shakarchi, Real Analysis and Introduction, Newage International.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests	20
Online test of MCQs / Short Answer Questions / Long Answer	

Questions	
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Calculus on manifolds
Course Code	PSMT403
Class	M.Sc II
Semester	4
No of Credits	6
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	The generalization of differential and Integral calculus to differentiable manifolds. Manifolds are important objects in mathematics because they allow more complicated structures to be expressed and understood in terms of the relatively well-understood properties of simpler spaces.

Nomenclature: Calculus on Manifolds

Course Outcomes:

CO1: Students will be able to grasp the concept of tensor, alternating tensor, wedge product and differential forms.

CO2: Students will be able to understand fields and forms on manifolds.

CO3: Students will be able to understand the application of Classical theorems: Stoke's theorem, Green's theorem, Gauss divergence theorem.

Unit No.	Units	No. of lectures
1	Multilinear Algebra	15
2	Differential Forms	15
3	Basics of Submanifolds Of R^n	15

4	Stoke's Theorem	15
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Curriculum:

Unit	Title	Learning Points	No of Lectures
1	Multilinear Algebra	1.1 Multilinear map on a finite dimensional vector space V over R and k tensors on V , the collection of all k tensors on V , tensor product 1.2 Alternating Tensor And Collection of k tensors on V . 1.3 The exterior product (wedge product), basis of set of alternating k -tensors, 1.4 orientation of a finite dimensional vector space V over R .	15
2	Differential Forms	2.1 Differential forms: k -forms on R^n , wedge product of a k -form - and l - forms , 2.2 The exterior derivative and its properties 2.3 Pullback forms and its properties 2.4 closed and exact forms, Poincare's lemma.	15
3	Basics of Submanifolds Of R^n	3.1 Submanifolds of R^n , submanifold of R^n with boundary, Smooth functions defined on Submanifolds of R^n . 3.2 Tangent vector and Tangent	15

		<p>space of Submanifold of R^n.</p> <p>3.3 p-forms and differential p-forms on submanifold of R^n, exterior derivative of any differential p-forms on submanifold of R^n,</p> <p>3.4 Orientable Submanifold Of R^n and Oriented submanifolds of R^n, Orientation Preserving Map, Vector fields On Submanifold Of R^n, outward unit normal on boundary of submanifolds of R^n with non-empty boundary.</p>	
4	Stoke's Theorem	<p>4.1 Integral of a k-form on cube</p> <p>Integral of a k- form on an open subset A of R^k for a singular k-cube in A.</p> <p>4.2 Stoke's Theorem for k-cube</p> <p>4.3 Integration of a differentiable k- form on oriented k dimensional submanifolds M of R^n</p> <p>4.4 Change of variables theorem</p> <p>4.5 Stokes Theorem for submanifolds of R^k, Volume Element, Integration of functions on a submanifold of R^k, Classical theorems: Green's theorem, Divergence theorem of Gauss, Green's identities.</p>	15

Learning Resources recommended:

1. A.Browder, Mathematical Analysis, Springer International Edition, 1996.
2. V.Guillemin and A.Pollack, Differential Topology, AMS Chelsea Publishing, 2010.
3. J.Munkers, Analysis on Manifolds, Addison Wesley ,1997.
4. M.Spivak, Calculus on Manifolds, W. A. Benjamin Inc.,1965.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Skill based course : Linear and non - linear programming
Course Code	PSMT404
Class	M.Sc. II
Semester	IV
No of Credits	04
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	<p>In mathematics, nonlinear programming (NLP) is the process of solving an optimization problem where some of the constraints or the objective function are non linear. An optimization problem is one of calculation of the extrema (maxima, minima or stationary points) of an objective function over a set of unknown real variables and conditional to the satisfaction of a system of equalities and inequalities, collectively termed constraints. It is the sub-field of mathematical optimization that deals with problems that are not linear.</p> <p>In experimental science, some simple data analysis (such as fitting a spectrum with a sum of peaks of known location and shape but unknown magnitude) can be done with linear methods, but in general these problems are also nonlinear. Typically, one has a theoretical model of the system under study with variable parameters in it and a model of the experiment or experiments, which may also have unknown parameters. One tries to find a best fit numerically. In this case one often wants a measure of the precision of the result, as well as the best fit itself.</p>

Nomenclature: Skill based course: Linear and non - linear programming

Course Outcomes:

CO 1: Students will be able to construct objective functions, find a feasible region and find a solution set of an optimization problem.

- CO 2: Students will be able to use the simplex method to find an optimal vector for the standard linear programming problem and the corresponding dual problem.
- CO 3: Students will be able to use Lagrange multipliers to solve nonlinear optimization problems.
- CO 4: Students will be able to write down and apply Kuhn-Tucker conditions for constrained nonlinear optimization problems.
- CO 5: Students will be able to apply approximate methods for constraint problems.
- CO 6: Students will be able to apply basic line search methods to one-dimensional optimization problems, gradient methods, conjugate gradient methods to optimization problems

Unit No.	Units	No. of lectures
1	Linear Programming	15
2	Transportation Problems	15
3	Unconstrained Optimization	15
4	Constrained Optimization Problems	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Linear Programming	1.1 Operation Research 1.2 Linear Programming Problems 1.3 Convex sets 1.4 Simplex method 1.5 Duality theorem and sensitive analysis 1.6 Dual simplex method	15
II	Transportation Problems	2.1 Transportation problems 2.2 Assignment problems 2.3 Sequencing problem 2.4 Travelling salesperson problem	15

III	Unconstrained Optimization	3.1 Conditions for local optima 3.1.1 First order 3.1.2 Second order 3.2 One – dimensional search Methods 3.2.1 Golden Section Search 3.2.2 Fibonacci Search 3.2.3 Newton’s Method 3.2.4 Secant Method 3.2.5 Gradient Methods 3.2.6 Steepest Descent meth	15
IV	Constrained Optimization Problems	4.1 Problems with equality constraints 4.2 Tangent and normal spaces 4.3 Lagrange Multiplier Theorem 4.4 Second order conditions for equality constraints problems 4.5 Problems with inequality constraints 4.6 Karush-Kuhn-Tucker Theorem 4.7 Second order necessary conditions for inequality constraint problems	15

Learning Resources recommended:

- 1.E. K. P. Chong and S. H. Zak, Introduction to Optimization, Wiley-Int., 1996.
2. F. S. Hillier and G.J. Lieberman, Introduction to Operations Research (Sixth Edition),McGraw Hill, 1990.
3. G. Hadley, Linear Programming, Narosa Publishing House, 1995.
4. S. S. Rao, Optimization Theory and Applications, Wiley Eastern Ltd, New Delhi,1984.
5. Rangarajan and K. Sundaram, A First Course in Optimization Theory, CambridgeUniversity Press, 1996.
6. K. Swarup, P. K. Gupta and Man Mohan, Operations Research, S. Chand and sons, New Delhi, 2010.
7. H. A. Taha, Operations Research-An introduction, Macmillan Publishing Co. Inc.,1997.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests	20
Online test of MCQs / Short Answer Questions / Long Answer Questions	
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Computational Algebra
Course Code	PSMT405
Class	M.Sc. II
Semester	III
No of Credits	05
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	In mathematics, computational algebra is a scientific area that refer to the study and development of algorithms and software for manipulating mathematical expressions and other mathematical objects. Computer algebra is widely used to experiment in mathematics and to design the formulas that are used in numerical programs.

Nomenclature: Computational Algebra

Course Outcomes:

CO1: Students will learn about algebraic numbers, algebraic integers and further properties of rings of integers.

CO2: Students will understand the class group.

CO3. Students will gain knowledge of Ramification theory and Diophantine equations

Unit No.	Units	No. of lectures
1	Representation Theory	15
2	Group theory software	15
3	Ideals, Varieties and Algorithms	15
4	Commutative Algebra software	15

Curriculum:

Unit	Title	Learning Points	No of Lectures
I	Representation Theory	Linear representations of a finite group on a finite dimensional vectorspace over C . If ρ is a representation of a finite group G on a complex vectorspace V , then there exists a G -invariant positive definite Hermitian inner product on V . Complete reducibility (Maschke's theorem). The space of class functions, Characters and Orthogonality relations. For a finite group G , there are finitely many isomorphism classes of irreducible representations, the same number as the number of conjugacy classes in G . Two representations having same character are isomorphic. Regular representation. Schur's lemma and proof of the Orthogonality relations. Every irreducible representation over C of a finite Abelian group is one dimensional. Character tables with emphasis on examples of groups of small order.	15

II	Group theory software	Introduction to Sage Math and GAP softwares. Permutation groups, examples, Groups with generators, center of a group, derived series examples, Character tables, Matrices over finite fields.	15
III	Ideals, Varieties and Algorithms	Polynomials in one variable, Affine spaces, Parameterizations of Affine varieties, Polynomial rings in more variables, Dickson's lemma, Hilbert basis theorem, Basics of invariant theory, Groebner basis, Buchberger Algorithm and Applications.	15
IV	Commutative Algebra software	Introduction to Singular and Macaulay. Polynomials in more than two variables over fields, quotient rings, localizations, Groebner bases.	15

Learning Resources recommended:

1. M. Artin, Algebra, Prentice Hall of India, 2011.
2. David A. Cox, John Little and Donal O'Shea, Ideals, Varieties, and Algorithms, Springe,2015.
3. S. Sternberg, Group theory and Physics, Cambridge University Press, 1994. 4. Bernd Sturmfels, Algorithms in Invariant Theory, Springer, 2008.

Evaluation Pattern

A. Continuous Internal Evaluation (40 marks)

Method	Marks
Online / Class Tests Online test of MCQs / Short Answer Questions / Long Answer Questions	20
Assignments / seminars /viva	10
Attendance and overall performance	10

B. Semester End Evaluation (60 M)

Comprehensive written examination of 2-hour duration will be conducted at the end of each semester to evaluate students' understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions or fill in the blanks or one line sentence, short answer questions and descriptive type questions, problems.

Question Paper Pattern (60M – 2 hours)

Q. No	Unit	Marks
1	I	12
2	II	12
3	III	12
4	IV	12
5	I	03
	II	03
	III	03
	IV	03

Syllabus for M.Sc. Mathematics Autonomous from the year 2023-24

Name of the Course	Project course
Course Code	PSMT406
Class	M.Sc II
Semester	Semester IV
No of Credits	4
Nature	Project
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	When Student studies a project course, he learns all the specific techniques, skills and programs which are useful to manage working schedules effectively against a deadline. When you plan your projects well, he can foresee challenges to manage risks, prioritize accordingly and keep his eyes on the end goal.

	<p>When students study project management, they learn how each project can be broken down into a clear process of assigned tasks, milestones, and deadlines. The skills that students get to learn and practice are Analytical thinking and innovation, Active learning, Problem solving, Critical thinking, Leadership and social influence, Reasoning, problem solving and ideation, Resilience, stress tolerance and flexibility.</p> <p>Project managers are needed across all industries, but they are particularly in the following industry areas: Engineering and Construction, Community Services and Healthcare, Banking and Financial Services, Infrastructure, Manufacturing, Law, Information Technology, Government and Defence, Education and Training, Oil and Gas, Retail, Professional services and consulting.</p>
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Nomenclature: Project Course

Course Outcomes:

- CO1 : Student will be able to decide the problem accurately.
- CO2 : Student will learn various methods of collection of the data .
- CO3 : Student will learn various methods to analysis the data.
- CO4 : Student will be able to draw the conclusion from analysis.
- CO5 : Student will be able to suggest the solution for the current problem.
- CO6 : Students will be able to present their project through powerpoint presentations

Curriculum:

Sr.no	stage	Learning Points	No of Lectures
1	Deciding project problem	---	60
2	Data collection	---	
3	Data analysis	---	
4	conclusion, powerpoint presentation	---	

The stages of the project can be changed as per the need of the topic of project.

The comparative study or different techniques to solve the same problem such type of projects can be done

Learning Resources recommended:

According to topic selected, various books should be referred.

Evaluation Pattern

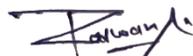
A. Continuous Internal Evaluation (40 marks)

Method	Marks
Attendance	10
Efforts, consistency, sincerity towards project	10
Skills adopted	20

B. Semester End Evaluation (60 marks)

The Project is to be presented by a group of at most 3 students. The evaluation of project is to be done by the committee of 2 members on following criteria-

Criteria	Marks
Contents Of The Project	30
Powerpoint Presentation Of The Project	20
Viva The Project	10



Name and Signature: Dr. Diwakar P. Karwanje

Chairman of BoS of Mathematics