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 Programme

Two Year Integrated Programme

Four Semesters

Syllabus for Semester : III & IV

Under Choice Based Credit System (CBCS)

To be implemented from Academic Year- 2024-2025

Name of Programme	**M.Sc. Mathematics**
Level	PG
No of Semesters	04
Year of Implementation	**2024-25**
Programme Specific Outcomes (PSO)	1. Learner shall able to demonstrate an understanding of commonly used facts, formulae, terminology and definitions. 2. Learner shall able to write well-constructed and logical mathematical proofs. 3. Learner shall get advanced knowledge of principles, methods and clear perception of innumerous power of mathematical ideas and tools. 4. Learner shall get knowledge about both pure as well as applied mathematics branches
Relevance of PSOs to the local, regional, national, and global developmental needs	The study of M.Sc. Mathematics helps to 1. Inculcate critical thinking to carry out scientific investigation objectively without being biased, prepare learners for pursuing research or careers in industry in mathematical sciences. 2. Create awareness to become an enlightened citizen with commitment to deliver one's responsibilities 3. 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 sources 4. 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.

Master of Science (M.Sc) Mathematics Programme

Under Choice Based Credit System

Course Structure

M.Sc. II

(To be implemented from Academic Year- 2024-25)

Course Code	Semester III	Credits	Course Code	Semester IV	Credits
Major Mandatory			Major Mandatory		
PSMT301	Algebra III	4	PSMT401	Algebra IV	4
PSMT302	Functional Analysis	4	PSMT402	Fourier Analysis	4
PSMT303	Geometry of Curves and Surfaces	4	PSMT403	Calculus on Manifolds	4
PSMT304	Discrete Mathematics II	2			
Major Electives (Any One)			Major Electives (Any One)		
PSMT305	Graph Theory	4	PSMT404	Numerical Analysis	4
PSMT306	Linear & Non-Linear Programming		PSMT405	Operation Research	
PSMT307	Research Project	4	PSMT406	Research Project	6
Total Credits		22	Total Credits		22

Teaching Pattern :

1. Four lectures per week per course of 4 credits.
2. Two lectures per week per course of 2 credits.

Revised Syllabus of Courses of
Master of Science (M.Sc.) Mathematics Programme at Semester III
with Effect from the Academic Year 2024-2025

Course Code	Semester III	Credits
Major Mandatory		
PSMT301	Algebra III	4
PSMT302	Functional Analysis	4
PSMT303	Geometry of Curves and Surfaces	4
PSMT304	Discrete Mathematics II	2
Major Electives (Any One)		
PSMT305	Graph Theory	4
PSMT306	Linear & Non-Linear Programming	4
PSMT307	Research Project	4
Total Credits		22

Name of the Course	Algebra III
Course Code	PSMT301
Class	M.Sc.
Semester	III
No. of Credits	4
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.

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

Nomenclature : Algebra III

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. Learn Classical groups like Simple groups, Solvable groups and Nilpotent groups and applications of these classical groups
2. Learn Finitely generated modules, Free modules, Free modules of rank n
3. Structure theorem for finitely generated modules over a PID and Applications to the Structure theorem for finitely generated Abelian groups and linear operators

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Curriculum :

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

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.
4. Introduction to Commutative Algebra by M.F.Atiyah, I.G.Macdonald , Addisom Wesley Publishing Company.

Evaluation Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

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

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Name of the Course	Functional Analysis
Course Code	PSMT302
Class	M.Sc.
Semester	III
No. of Credits	4
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.

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

Nomenclature: Functional Analysis

Course Outcomes:

On successful completion of this course, a learner will be able to:

1. learn Hilbert spaces and Banach spaces
2. 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.

Curriculum :

Unit No.	Title and Learning Points	
1	Baires spaces and Hilbert spaces	15 Lectures
	1.1 Baire spaces, Hilbert Spaces, Inner product induced by norm, Bessel's Inequality 1.2 orthogonal decomposition, Parseval's identity	
2	Normed Linear Spaces	15 Lectures
	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	
3	Bounded Linear Transformations	15 Lectures
	4.1 Bounded linear transformations, Equivalent characterizations 4.2 Dual Space of a Normed Linear Space, Riesz Representation theorem for Hilbert spaces 4.3 Separable spaces, examples of separable spaces.	
4	Basic Theorems	15 Lectures
	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.	

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.
8. Functional Analysis – A first Course by S.Kumerasan, D.Sukumar , Narosa Publication.

Evaluation Scheme:

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

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

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Name of the Course	Geometry of Curves and Surfaces
Course Code	PSMT303
Class	M.Sc.
Semester	III
No. of Credits	4
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 work pieces. 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.

Unit No.	Units	No. of Lectures
1	Isometries of Euclidean space	15
2	Curves	15
3	Regular Surface	15
4	Curvature	15

Nomenclature: Geometry of Curves and Surfaces

Course Outcomes:

On successful completion of this course, a learner will be able to:

1. Understand types of isometries of Euclidean space and its properties.
2. Grasp parameterization of curves and surfaces.
3. Understand the various geometrical aspects like tangent, arc length, curvature, torsion etc of plane and space curves.
4. 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.

Curriculum :

Unit No.	Title and Learning Points	
1	Isometries of Euclidean space	15 Lectures
	1.1 Orthogonal transformations, Reflection, Rotations and Translations. 1.2 Hyper-plane 1.3 Orientation Preserving and Reversing Isometries. 1.4 Glide reflection.	
2	Curves	15 Lectures
	2.1 Parameterized 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	
3	Regular Surface	15 Lectures
	3.1 Regular surfaces, Examples, Tangent Space to A Surface, Differential of smooth function 3.2 Orientable surfaces. The Mobius band is not orientable	
4	Curvature	15 Lectures
	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	

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, Linear Algebra, A Geometric Approach, 2000.
5. A. Pressley, Elementary Differential Geometry, Springer UTM.

Evaluation Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

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

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Name of the Course	Discrete Mathematics
Course Code	PSMT304
Class	M.Sc.
Semester	III
No. of Credits	2
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	

Unit No.	Units	No. of Lectures
1	Recurrence Relations	15
2	Polya's Theory of counting	15

Nomenclature : Discrete Mathematics

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. Learn the Fibonacci sequence, the Linear homogeneous recurrence relations with constant coefficient, Ordinary and Exponential generating Functions, exponential generating function for bell numbers, the applications of generating, Functions to counting and use of generating functions for solving recurrence relations
2. Understand Polyas Theory of counting, Orbit stabilizer theorem, Burnside Lemma and its applications, Applications of Polya's Formula

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Curriculum :

Unit No.	Title and Learning Points
1	Recurrence Relations 15 Lectures
	1.1 The Fibonacci sequence, Linear homogeneous and Non-homogeneous recurrence relations. Proof of the solution Linear homogeneous recurrence relations with constant coefficient in case of distinct roots and statement of the theorem giving a general solution (in case of repeated roots), Iteration and Induction. 1.2 Ordinary generating Functions, Exponential Generating Functions, algebraic manipulations with power series, generating functions for counting combinations with and without repetitions, applications to counting, use of generating functions for solving homogeneous and non-homogeneous recurrence relations
2	Polya's Theory of counting 15 Lectures
	2.1 Equivalence relations and orbits under a permutation group action. Orbit Stabiliser theorem 2.2 Burnside Lemma and its applications, Cycle index, Polyas Formula, Applications of Polyas Formula

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Learning Resources Recommended :

1. Richard A. Brualdi: Introductory Combinatorics, Pearson
2. A. Tucker: Applied Combinatorics, John Wiley & Sons.
3. Kenneth Rosen: Discrete Mathematics and its applications, Tata McGraw Hills

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Evaluation Scheme :

A. Continuous Evaluation (20 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 10 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best one out of three will be considered)	10
Assignments / Seminar / Group discussion	05
Attendance and active participation in classroom	05

B. Semester End Evaluation (30 Marks - 1 Hour)

Comprehensive written examination of 1-hour duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

Question No.	Unit	Marks
1	I	15
2	II	15

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Name of the Course	Graph Theory
Course Code	PSMT305
Class	M.Sc.
Semester	III
No. of Credits	4
Nature	Theory
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	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 model maker, data analyst.

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

Nomenclature : Graph Theory

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. Learn basic concepts of graphs, vertices, edges types of graphs
2. Learn special type of graph: Tree and their properties
3. Learn to identify Eulerian and Hamiltonian Graph
4. Learn Matching in Graphs and its applications.

Curriculum :

Unit No.	Title and Learning Points	
1	Connectivity	15 Lectures
	1.1 Basic concepts from Graph Theory, Types of Graphs 1.2 Havel Hakimi Algorithm, Bipartite Results 1.3 Isomorphism, Adjacency Matrix, Incidence Matrix 1.4 Dijkstra's Algorithm, Connectivity, Menger's Theorem	
2	Trees	15 Lectures
	2.1 Characterization of Trees, Theorems related with tree 2.2 Kruska's, Prim's Algorithm 2.3 Rooted Tree, BFS, DFS Algorithms 2.4 Spanning Trees, Cayley's Formula 2.5 Huffman Coding	
3	Eulerian and Hamiltonian Graphs	15 Lectures
	3.1 Characterization of Eulerian Graph, Conditions for Eulerian Graphs 3.2 Fleury's Algorithm 3.3 Hamiltonian Graphs, Necessary Conditions for Hamiltonian Graphs 3.4 Hamiltonian Closure, Chvatal Theorem 3.5 Travelling Salesman Problem	
4	Matching and Ramsey Theory	15 Lectures
	4.1 Matching, Augmenting Path and definitions related with Matching 4.2 Matching in Bipartite Graph 4.3 Hall's Theorem, Konig's Theorem, Tutte's Theorem 4.4 Ramsey Theorem-Existence of r(k,l) 4.5 Graph Ramsey Theorem	

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 Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

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

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Name of the Course	Linear & Non-Linear Programming
Course Code	PSMT306
Class	M.Sc.
Semester	III
No. of Credits	4
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	In mathematics, **nonlinear programming** (**NLP**) is the process of solving an optimization problem where some of the constraints or the objective function are nonlinear. 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. 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.

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

Nomenclature : Linear & Non-Linear Programming

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. construct objective functions, find a feasible region and find a solution set of an optimization problem
2. use the simplex method to find an optimal vector for the standard linear programming problem and the corresponding dual problem
3. use Lagrange multipliers to solve nonlinear optimization problems
4. write down and apply Kuhn-Tucker conditions for constrained nonlinear optimization problems
5. apply approximate methods for constraint problems
6. apply basic line search methods to one-dimensional optimization problems, gradient methods, conjugate gradient methods to optimization problems

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Curriculum :

Unit No.	Title and Learning Points	
1	Linear Programming	15 Lectures
	1.1 Operation Research: scope and necessity in industry 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	
2	Transportation Problems	15 Lectures
	2.1 Transportation problems 2.2 Assignment problems 2.3 Sequencing problems 2.4 Travelling salesman problem	
3	Unconstrained Optimization	15 Lectures
	3.1 First and second order conditions for local optima 3.2 One-Dimensional Search Methods: Golden Section Search, Fibonacci Search, Newton's Method, Secant Method, Gradient Methods, Steepest Descent method.	
4	Constrained Optimization Problems	15 Lectures
	4.1 Problems with equality constraints 4.2 Tangent and normal spaces, Lagrange Multiplier Theorem 4.3 Second order conditions for equality constraints problems	

	4.4 Problems with inequality constraints, Karush-Kuhn-Tucker Theorem 4.5 Second order necessary conditions for inequality constraint problems

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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, Cambridge University Press, 1996.
6. H. A. Taha, Operations Research-An introduction, Macmillan Publishing Co. Inc.,1997.

Evaluation Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern:

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

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Name of the Course	Research Project
Course Code	PSMT307
Class	M.Sc. II
Semester	Semester III
No of Credits	4
Nature	Project
Type	Core
Highlight revision specific to employability/ entrepreneurship/ skill development	When learner studies a project course, they learn 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. When students study project management, he learns how each project can be broken down into a clear process of assigned tasks, milestones, and deadlines. The skills that student 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 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 Defense, Education and Training, Oil and Gas Retail, Professional services and consulting

Nomenclature : Research Project

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. Decide the problem accurately.
2. Learn various methods of collection of the data
3. Learn various methods to analysis the data
4. Make the conclusion from analysis, Suggest the solution for the current problem
5. Learn presentation skills

Curriculum :

Unit No.	Title and Learning Points	
1	Project Work	60 Lectures
	1.1 Identifying problem for project, Survey, Deciding Methodology 1.2 Implementation of Project, Data Analysis and Conclusion. 1.3 Project Report	

Learning Resources Recommended :

1. Research Papers
2. Journals
3. Internet

Guidelines for the project :

- A learner is expected to work 60 hours in the semester for the research project.
- The project is to be taken by a group of at most 3 learners.
- The project report should be file bound/spiral bound/hard bound.
- At the end of semester learner should submit a detailed project report at the time of viva.

Format of Project Report :

The project report should contain following points.

Title Page, Certificate of Completion, Declaration, Acknowledgments, Table of Contents, Abstract, Introduction, Methodology, Observation and Data Analysis, Conclusion, References & Appendices.

Evaluation Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Project Presentation in the mid semester	25
Attendance and active participation in project	15

B. Semester End Evaluation (60 Marks)

The evaluation of project will be examined by external examiners on following criteria.

Criteria	Marks
Contents of the Project	25
Data Collection	15
Presentation	15
Viva	05

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Revised Syllabus of Courses of
Master of Science (M.Sc.) Mathematics Programme at Semester IV
with Effect from the Academic Year 2024-2025

Course Code	Semester IV	Credits
Major Mandatory		
PSMT401	Algebra IV	4
PSMT402	Fourier Analysis	4
PSMT403	Calculus on Manifolds	4
Major Electives (Any One)		
PSMT404	Numerical Analysis	4
PSMT405	Operation Research	4
PSMT406	Research Project	6
Total Credits		22

Name of the Course	Algebra IV
Course Code	PSMT401
Class	M.Sc.
Semester	III
No. of Credits	4
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''. Galois theory has been used to solve classic problems including showing that two problems of antiquity cannot be solved as they were stated (doubling the cube and trisecting the angle), and characterizing the regular polygons that are constructible Galois' theory also gives a clear insight into questions concerning problems in compass and straightedge construction. It gives an elegant characterization of the ratios of lengths that can be constructed with this method. Using this, it becomes relatively easy to answer such classical problems of geometry.

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

Nomenclature : Algebra IV

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. Understand 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
2. Learn Finite fields as splitting fields are visualized and the notion of algebraic closure is discussed in detail
3. Learn Galois extensions are studied and the fundamental theorem of Galois theory is established
4. 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

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Curriculum :

Unit No.	Title and Learning Points	
1	Algebraic Extensions	15 Lectures
	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	
2	Normal and Separable Extensions	15 Lectures
	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	
3	Galois Theory	15 Lectures
	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	
4	Applications	15 Lectures
	4.1 Cyclotomic field $Q(\zeta_n)$. Cyclotomic polynomial 4.2 Galois group for an irreducible quartic polynomial. 4.3 Galois group and Abel's theorem on the insolvability of a general quintic polynomial	

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 Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

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

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Name of the Course	Fourier Analysis
Course Code	PSMT402
Class	M.Sc.
Semester	IV
No. of Credits	4
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.

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

Nomenclature : Fourier Analysis

Course Outcomes:

On successful completion of this course, a learner will be able to:

1. Understand the Fourier series expansion of a periodic function and their convergence.
2. To grasp properties of the Dirichlet kernel, Fejer kernel, Poisson kernel and the concept of a good kernel.
3. Aware about application of a Fourier series in the solution of the Dirichlet problem and heat equation.

Curriculum:

Unit No.	Title and Learning Points
1	Fourier Series 15 Lectures
	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.
2	Dirichlet's theorem 15 Lectures
	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.
3	Fejer Theorem and applications 15 Lectures
	3.1 Cesaro summability, Cesaro means and Cesaro sum of the Fourier Series 3.2 Fejer's Kernel, Fejer's kernel is a good kernel, Fejer Theorem, Parseval's Identity, Convergence of Fourier series of an L^2 periodic functions are theL^2-norm, Riesz-Fischer theorem. 3.3 Unitary isomorphism from L^2 onto the sequence space of square summable complex sequences.
4	Dirichlet Problem In The Unit Disc 15 Lectures
	4.1 Abel Summability, Abel sum of the Fourier Series, The Poisson kernel, The Poisson kernel is a good kernel. 4.2 Laplacian, Harmonic Functions, Dirichlet Problem for the Unit Disc, The solution of the Dirichlet problem for the unit disc, the Poisson integral. 4.3 Applications of Fourier Series to Heat Equation on the Circle.

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 Scheme:

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern:

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

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Name of the Course	Calculus on Manifolds
Course Code	PSMT403
Class	M.Sc.
Semester	IV
No. of Credits	4
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.

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

Nomenclature: Calculus on Manifolds

Course Outcomes:

On successful completion of this course, a learner will be able to:

1. Grasp the concept of tensor, alternating tensor, wedge product and differential forms.
2. Understand fields and forms on manifolds.
3. Understand the application of Classical theorems: Stoke's theorem, Green's theorem, Gauss divergence theorem.

Curriculum :

Unit No.	Title and Learning Points
1	Multilinear Algebra 15 Lectures
	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.
2	Differential Forms 15 Lectures
	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.
3	Basics of Sub manifolds of R^n 15 Lectures
	3.1 Sub manifolds of R^n, submanifold of R^n with boundary, Smooth functions defined on Submanifolds of R^n. 3.2 Tangent vector and Tangent space of Submanifold of R^n. 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, 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.
4	Stoke's Theorem 15 Lectures
	4.1 Integral of a k-form on cube Integral of a k- form on an open subset A of R^k for a singular k-cube in A 4.2 Stoke's Theorem for k-cube, Integration of a differentiable k- form on oriented k dimensional submanifolds M of R^n 4.3 Change of variables theorem, Stokes Theorem for submanifolds of R^k, 4.4 Volume Element, Integration of functions on a submanifolds of R^k, Classical theorems: Green's theorem, Divergence theorem of Gauss, Green's identities.

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 Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern :

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

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Name of the Course	Numerical Analysis
Course Code	PSMT404
Class	M.Sc.
Semester	IV
No. of Credits	4
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.

Unit No.	Units	No. of Lectures
1	Approximation of functions	15
2	Differential and Difference Equations	15
3	Numerical Integration	15
4	Numerical Solutions of Partial Differential Equations	15

Nomenclature : Numerical Analysis

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. grasp the concept of numerical solution of various mathematical problems and corresponding errors.
2. solve the problems on approximation of functions by least square method.
3. apply various numerical techniques in the solution of difference equations, ordinary and partial differential equations.

Curriculum :

Unit No.	Title and Learning Points
1	Approximation of functions — 15 Lectures
	1.1 Least square approximation 1.2 Weighted least squares method 1.3 Gram-Schmidt orthogonalizing process 1.4 Least square approximation by chebyshev polynomial
2	Differential and difference equations — 15 Lectures
	2.1 Differential equations: Solution of linear differential equations with constant coefficients by Predictor corrector methods and Milne's method 2.2 Galerkin's Method for two-point linear boundary value problems 2.3 Difference equations: Linear differential equations with constant coefficients and methods of solving them
3	Numerical Integration — 15 Lectures
	3.1 Derivation of a formula for numerical integration in terms of finite difference and its special cases viz. Trapezoidal, Simpson's $\frac{1}{3}$ rule and Simpson's $\frac{3}{8}$ rule. Boole's and Weddle's rule 3.2 Gauss-Legendre numerical integration 3.3 Gauss-Chebyshev numerical integration 3.4 Gauss-Hermite numerical integration 3.5 Gauss-Laguree numerical integration, with the derivation of all methods using the method of undetermined coefficients. 3.6 Romberg's method 3.7 Multiple integrals
4	Numerical solution of partial differential equations — 15 Lectures
	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

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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, New Age 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 Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern:

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

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Name of the Course	Operations Research
Course Code	PSMT405
Class	M.Sc.
Semester	IV
No. of Credits	4
Nature	Theory
Type	Elective
Highlight revision specific to employability/ entrepreneurship/ skill development	Operations research (OR) is an analytical method of problem-solving and decision-making that is useful in the management of organizations. In operations research, problems are broken down into basic components and then solved in defined steps by mathematical analysis.

Unit No.	Units	No. of Lectures
1	Decision Analysis	15
2	Games and Strategies	15
3	Network Routing Problem	15
4	Network Scheduling by CPM / PERT	15

Nomenclature : Operations Research

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. apply operations research methodologies.
2. solve various problems practically.
3. analyse the situations and interpret the solution obtained using operations research methodologies.

Curriculum :

Unit No.	Title and Learning Points
1	Decision Analysis 15 Lectures
	1.1 Introduction 1.2 Decision – making Problem, Decision – making Process 1.3 Decision – making Environment 1.4 Decision Under Uncertainty, Decision Under Risk 1.5 Decision – Tree Analysis 1.6 Decision – making With Utilities
2	Games and Strategies 15 Lectures
	2.1 Introduction, Two-person zero sum game 2.2 Some basic terms 2.3 The Maximin – Minimax Principle, Games without saddle point – Mixed Strategies 2.4 Graphic Solution of 2 x n and m x 2 Games 2.5 Dominance Property, Arithmetic method for n x n Games 2.6 General Solution of m x n Rectangular Games 2.7 Games against passivity, Limitations and extensions
3	Network Routing Problems 15 Lectures
	3.1 Introduction 3.2 Network flow problems, Minimal spanning tree problem 3.3 Shortest route problems 3.4 More applications of shortest route problem 3.5 Maximal flow problems, Minimum cost flow problems
4	Network Scheduling By CPM/PERT 15 Lectures
	4.1 Introduction 4.2 Network: Basic Components, Logical Sequencing 4.3 Rules of Network Construction 4.4 Concurrent Activities, Critical Path Analysis 4.5 Probability Consideration in PERT, Distinction between PERT and CPM

Learning Resources Recommended :

1. Operations Research, K. Swarup, P.K. Gupta & Man Mohan, S. Chand & Sons, new Delhi, 2010
2. Operations Research - An Introduction, H. A. Taha, Macmillan Publication Co. Inc., 1997
3. Operations Research - Theory and applications, J. N. Sharma, Macmillan India Limited, 1997
4. Operations Research - Technique for Management, V. K. Kapoor, S. Chand & Sons, New Delhi, 2001

Evaluation Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Unit Test - (MCQ / Descriptive - Based on Theory and/or Problems - Online/Offline – 1 Unit test of 20 marks / 2 Unit tests of 10 marks each / 3 Unit tests of 10 marks each and best two out of three will be considered)	20
Assignments / Seminar / Group discussion	10
Attendance and active participation in classroom	10

B. Semester End Evaluation (60 Marks - 2 Hours)

Comprehensive written examination of 2-hours duration will be conducted at the end of each semester to evaluate learner's understanding of the course material. The examination will cover the entire syllabus and include a mix of multiple-choice questions, short answer questions and descriptive type questions.

Question Paper Pattern:

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

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Name of the Course	Research Project
Course Code	PSMT406
Class	M.Sc. II
Semester	Semester IV
No of Credits	6
Nature	Project
Type	Research Projects
Highlight revision specific to employability/ entrepreneurship/ skill development	When learner studies a project course, they learn 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. When students study project management, he learns how each project can be broken down into a clear process of assigned tasks, milestones, and deadlines. The skills that student 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 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 Defense, Education and Training, Oil and Gas Retail, Professional services and consulting

Nomenclature : Research Project

Course Outcomes :

On successful completion of this course, a learner will be able to:

1. Decide the problem accuretly.
2. Learn various methods of collection of the data
3. Learn various methods to analysis the data
4. Make the conclusion from analysis, Suggest the solution for the current problem
5. Learn presentation skills

Curriculum :

Unit No.	Title and Learning Points
1	Project Work 90 Lectures
	1.1 Identifying problem for project, Survey, Deciding Methodology 1.2 Implementation of Project, Data Analysis and Conclusion. 1.3 Project Report

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Learning Resources Recommended :

1. Research Papers
2. Journals
3. Internet

Guidelines for the project :

- A learner is expected to work 90 hours in the semester for the research project.
- The project is to be taken by a group of at most 3 learners.
- The project report should be file bound/spiral bound/hard bound.
- At the end of semester learner should submit a detailed project report at the time of viva.

Format of Project Report :

The project report should contain following points.

Title Page, Certificate of Completion, Declaration, Acknowledgments, Table of Contents, Abstract, Introduction, Methodology, Observation and Data Analysis, Conclusion, References & Appendices.

Evaluation Scheme :

A. Continuous Evaluation (40 Marks)

Method	Marks
Project Presentation in the mid semester	25
Attendance and active participation in project	15

B. Semester End Evaluation (60 Marks)

The evaluation of project will be examined by external examiners on following criteria.

Criteria	Marks
Contents of the Project	25
Data Collection	15
Presentation	15
Viva	05

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Name and Signature: Dr. Diwakar P. Karwanje
Chairman of BoS of Mathematics