FOUR-YEAR UNDERGRADUATE PROGRAMME

Under National Education Policy (NEP-2020)

STRUCTURE AND SYLLABUS

(As recommended by the Board of Studies for Mathematics on 16th July 2025)

(With effect from the Academic Session 2025-2026)

DEPARTMENT OF MATHEMATICS

VISVA-BHARATI

SANTINIKETAN-731 235

WEST BENGAL, INDIA

COURSE STRUCTURE OF FOUR-YEAR UNDERGRADUATE (UG) PROGRAMME IN MATHEMATICS

NcrF Credit Level	Semester	Major Courses (MJ)	Minor Courses (MN)	Multi Courses (MD)	AECC	SEC	CVAC	Research *	Internship	Total Credits	Degree
4.5 (Sem I & II)	I	2x4cr=8cr	MN-A 1x4cr=4cr	1x3cr=3cr	ENG/MIL1 1x2cr=2cr	1x3cr=3cr	TS 1x3cr=3cr	---		23	UG Certificate
	II	2x4cr=8cr	MN-B 1x4cr=4cr	1x3cr=3cr	ENG/MIL2 1x2cr=2cr	1x3cr=3cr	ES 1x3cr=3cr	---		23	
1st Cumulative Credits	YEAR 1	2x8cr=16 credits	2x4cr=8 credits	2x3cr=6 credits	2x2cr=4 credits	2x3cr=6 credits	2x3cr=6credits	---	Summer Internship 4 credits	46+4	
	After successful completion of ONE-YEAR Course (Semesters - I & II) securing 46 credits + 4 credits vocational summer internship, students may exit with UG Certificate in MATHEMATICS or continue further.										
5.0 (Sem I to IV)	III	2x4cr=8cr	MN-A 1x4cr=4cr	1x3cr=3cr	MIL/ENG1 1x2cr=2cr	1x3Cr=3cr	---	---		20	UG Diploma
	IV	4x4cr=16cr	MN-B 1x4cr=4cr	---	MIL/ENG2 1x2cr=2cr	---	---	---		22	
2nd Cumulative Credits	YEAR 2	10x4cr=40 credits	4x4cr=16 credits	3x3cr=9credits	4x2cr=8 credits	3x3cr=9credits	2x3cr=6credits	---	Summer Internship 4 credits	88+4	
	After successful completion of TWO-YEAR Course (Semesters - I to IV) securing 88 credits + 4 credits vocational summer internship, students may exit with UG Diploma in MATHEMATICS or continue further.										
5.5 (Sem I to VI)	V	3x4cr=12 cr	MN-A 1x4cr=4cr	---	---	---	---	---		16	Bachelor's Degree
	VI	3x4cr=12 cr	MN-B 1x4cr=4cr	---	---	---	---	---		16	
3rd Cumulative Credits	YEAR 3	16x4cr=64 credits	6x4cr=24 credits	3x3cr=9 credits	4x2cr=8 credits	3x3cr=9credits	2x3cr=6credits	---	Summer Internship 4 credits	120+4	
	After successful completion of THREE-YEAR COURSE (Semesters - I to VI) securing 120 credits + 4 credits vocational summer internship, students may exit with UG Degree in MATHEMATICS or continue further.										
6 (Sem I to VIII)	VII	4x4cr=16 cr	MN-A 1x4cr=4cr	---	---	---	---	---		20	Bachelor's Degree (Honours)
	VIII	4x4cr=16 cr	MN-B 1x4cr=4cr	---	---	---	---	---		20	

4th Cumulative Credits	**YEAR 4**	**24x4cr=96 credits**	**8x4cr=32 credits**	**3x3cr=9credits**	**4x2cr=8 credits**	**3x3cr=9credits**	**2x3cr=6credits**	**---**	**Summer Internship 4 credits**	**160+4**	
After successful completion of FOUR-YEAR COURSE (Semesters - I to VIII) securing 160 credits + 4 credits vocational summer internship, students may obtain Bachelor's degree (Honours) in MATHEMATICS.											
OR											
6.0 (Sem I to VIII)	**VII**	**3x4cr=12 cr**	**MN-A 1x4cr=4cr**	**---**	**---**	**---**	**---**	**1x4cr=4cr***		**20**	**Bachelor's degree (Honours with Research)**
	VIII	**2x4cr=8cr**	**MN-B 1x4cr=4cr**	**---**	**---**	**---**	**---**	**2x4cr=8cr***		**20**	
4th Cumulative Credits	**YEAR 4**	**21x4=84credits**	**8x4=32credits**	**3x3cr=9credits**	**4x2cr=8 credits**	**3x3cr=9credits**	**2x3cr=6credits**	**3x4cr=12 credits**	**Summer Internship 4 credits**	**160+4**	
After successful completion of FOUR-YEAR COURSE (Semesters - I to VIII) securing 160 credits + 4 credits vocational summer internship, students may obtain Bachelor's degree (Honours with Research) in MATHEMATICS.											

Dissertation can be opted by students who attain at least CGPA 75% in 3 years and desire to obtain the Bachelor's degree (Honours with Research). The students pursuing Bachelor's degree (Honours with Research) have to secure 12 credits (4 credits in Semester VII and 8 credits in Semester VIII). However, students pursuing only Bachelor's degree (Honours) have to study additional three Major Courses in MATHEMATICS securing 12 credits (4 credits in Semester VII and 8 credits in Semester VIII) in lieu of the Dissertation.

Learning Outcome based Curriculum for FOUR-YEAR UNDERGRADUATE (UG) PROGRAMME IN MATHEMATICS following NEP 2020

MAJOR COURSES in MATHEMATICS [Discipline-Specific Core Courses]

Course Code	Course Type	Course Title	Credits	Marks	Hours
SEMESTER I					
MJMA01	Theory	Introduction to groups and Analysis I	2+2	50+50	
MJMA02	Theory	Analytical Geometry and Vector & Tensor Calculus	2+2	50+50	
		Total	**8 credits**	**200**	
SEMESTER II					
MJMA03	Theory	Linear Algebra over R and Analysis II	2+2	100	
MJMA04	Theory	Ordinary Differential Equations I	4	100	
		Total	**8 credits**	**200**	
ONE-YEAR CERTIFICATE PROGRAMME TOTAL 4 MAJOR COURSES			**16 credits**	**400**	
SEMESTER III					
MJMA05	Theory	Analysis III and **IKS I** (Infinite Series in Kerala Mathematics)	3+1	100	

MJMA06	Theory	Ordinary Differential equation II and Dynamics of a Particle	2+2	50+50	
		Total	**8 credits**	**200**	
SEMESTER IV					
MJMA07	Theory	Quotients and Homomorphisms	4	100	
MJMA08	Theory	Analysis IV	4	100	
MJMA09	Theory	Partial Differential Equations and Dynamics of a Rigid Body	2+2	50+50	
MJMA10	Theory	Mathematical Probability & Statistics and **IKS II (Mahalanobis Distance)**	3+1	75+25	
		Total	**16 credits**	**400**	
TWO-YEAR UG DIPLOMA PROGRAMME TOTAL 10 MAJOR COURSES			**40 credits**	**1000**	
SEMESTER V					
MJMA11	Theory	Linear Algebra	4	100	
MJMA12	Theory	Analysis V	4	100	
MJMA13	Theory	Mathematical Modelling and Dynamical Systems	2+2	50+50	
		Total	**12 credits**	**300**	
SEMESTER VI					
MJMA14	Theory	Factorizations and Canonical Forms	4	100	
MJMA15	Theory	Analysis VI	4	100	
MJMA16	Theory	Numerical Analysis	4	100	
		Total	**12 credits**	**300**	
THREE-YEAR UG DEGREE PROGRAMME 16 MAJOR COURSES			**64 credits**	**1600**	
SEMESTER VII					
MJMA17	Theory	Introduction to Lebesgue Integration and Complex Analysis	2+2	50+50	
MJMA18	Theory	Linear operators on inner product spaces and Functional Analysis	2+2	50+50	
MJMA19	Theory	Advanced Ordinary Differential Equations and Advanced Partial Differential Equations	2+2	50+50	
		Total	**12 credits**	**300**	
Additional 4 Credit Course for Students having Marks < 75% to obtain Bachelor's Degree (Hons) without Research					
MJAMA01	Theory	Statics and Hydrostatics	2+2	50+50	
			4 credits	**100**	
SEMESTER VIII					
MJMA20	Theory	Advanced Group Theory and Classical Mechanics	2+2	50+50	
MJMA21	Theory	Methods of Applied Mathematics and **IKS III (Indian Astronomy)**	3+1	75+25	
		Total	**8 credits**	**200**	

Additional 8 Credit Course for Students having Marks < 75% to obtain Bachelor's Degree (Hons) without Research					
MJAMA02	Theory	Theory of Equations & **IKS IV (Algebra in Ancient India)** and Topology	(1+1)+2	(25+25)+50	
MJAMA03	Theory	Linear Programming Problem and Advanced Numerical Analysis	2+2	50+50	
			8 credits	**200**	
FOUR-YEAR BACHELOR'S DEGREE (with Honours) PROGRAMME 21 COURSES + 3 COURSES* (Optional in lieu of Dissertation for Honours students) FOUR-YEAR BACHELOR'S DEGREE (HONOURS with RESEARCH) PROGRAMME 21 COURSES + DISSERTATION			**84 credits + 12 credits**	**2100 + 300**	

MINOR COURSES in MATHEMATICS [Discipline-Specific Minor Courses]

Course Code	Course Type	Course Title	Credits	Marks	Hours
SEMESTER I					
MNMA01	Theory	Differential Calculus and **IKS V (Calculus in Ancient India)**, Integral Calculus, and Vector Calculus	(1+1)+1+1	(25+25)+25+25	
SEMESTER II					
MNMA01	Theory	Differential Calculus, Integral Calculus, and Vector Calculus	2+1+1	50+25+25	
ONE-YEAR UG CERTIFICATE PROGRAMME TOTAL 1 MINOR COURSE			**4**	**100**	
SEMESTER III					
MNMA02	Theory	Abstract and Linear Algebra	2+2	50+50	
SEMESTER IV					
MNMA02	Theory	Abstract and Linear Algebra	2+2	50+50	
TWO-YEAR UG DIPLOMA PROGRAMME TOTAL 2 MINOR COURSES			**8**	**200**	
SEMESTER V					
MNMA03	Theory	Differential Equations and their Applications	4	100	
SEMESTER VI					
MNMA03	Theory	Differential Equations and their Applications	4	100	
THREE-YEAR UG PROGRAMME TOTAL 3 MINOR COURSES			**12**	**300**	
SEMESTER VII					
MNMA04	Theory	Linear Programming Problem and Numerical Methods	2+2	50+50	
SEMESTER VIII					
MNMA04	Theory	Linear Programming Problem and Numerical Methods	2+2	50+50	
FOUR-YEAR BACHELOR'S DEGREE (HONOURS) PROGRAMME TOTAL 4 MINOR COURSES			**16**	**400**	

SKILL ENHANCEMENT COURSES in MATHEMATICS

Course Code	Course Type	Course title	Credits	Marks	Hours
SEMESTER I					
SEC01A	Theory	Programming in C-Theory	1	25	
SEC 01B	Practical	Programming in C-Laboratory	2	50	
SEMESTER II					
SEC02A	Theory	Artificial Intelligence & Machine Learning	1	25	
SEC02B	Practical	Python Programming	2	50	
ONE-YEAR CERTIFICATE PROGRAMME TOTAL 2 COURSES			**6 credits**	**150**	
SEMESTER III					
SEC03	Theory	Number Theory and Cryptography	3	75	
TWO-YEAR UG DIPLOMA PROGRAMME TOTAL 3 COURSES			**9 credits**	**225**	

MULTIDISCIPLINARY COURSE in MATHEMATICS

Course Code	Course Type	Course title	Credits	Marks	Hours
SEMESTER I /II/III					
MDMA01	Theory	**IKS VI (Ancient Indian Mathematics)**	3	75	

DETAILED SYLLABUS OF THE MAJOR COURSES IN MATHEMATICS

SEMESTER I

MJMA01 & MJMA02

MJMA01 (Unit-I: Introduction to groups)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Introduction to groups	MJMA01 (UNIT I)	2	10	40	50	2	0	0

Learning Objectives:

The objectives of this course are to:

- Introduce definition, examples and basic properties of groups, with a focus on cyclic groups.
- Study symmetry of plane figures through symmetric groups.
- Characterize subgroups of finite cyclic groups.
- Develop skills in mathematical proof writing in the context of abstract algebra.

Learning Outcomes:

After completion of this course, students will be able to:

- Explain and verify the group axioms with relevant examples.
- Identify subgroups and find number of subgroups of a finite cyclic group.
- Compute symmetric groups of basic plane figures and describe their group-theoretic properties.
- Write proofs of the results related to abstract algebra.

Syllabus

Introduction to groups, definition and examples of groups including symmetries of a square, dihedral groups, permutation groups, quaternion groups (illustration through matrices) and matrix groups. Elementary properties of groups, order of an element in a group. The groups Zn of all integers modulo n and Un of all units modulo n.

Definition and examples of subgroups, subgroup tests. Centralizer, normalizer, center of a group. Algebra of subgroups, product of two subgroups. Subgroups generated by a subset; generators and defining relations. Subgroups of the group of all integers.

Properties of cyclic groups, generators. Characterizations of the subgroups of a cyclic group.

Properties of permutations, cycle notation for permutations, even and odd permutations, alternating group. Order and conjugates of a permutation.

Books Recommended:

1. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
2. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., Wiley, 2011.
3. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2013.
4. Joseph A. Gallian, Contemporary Abstract Algebra, 9th Ed., Cengage, 2020.
5. I. N. Herstein, Topics in Algebra, 2nd Ed., Wiley, 2006.
6. Charles C. Pinter, A Book of Abstract Algebra, 2nd Ed., Dover, 2010.
7. Vivek Sahai and Vikas Bist, Algebra, 4th Ed., Alpha Science, 2018.
8. M. K. Sen, Shamik Ghosh, Parthasarathi Mukhopadhyay and Sunil Kumar Maity, Topics in Abstract Algbera, 4th Ed., Universities Press, 2022.

MJMA01 (Unit-II: Analysis I)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	ANALYSIS I	MJMA 01	2	10	40	50	2	0	0

Learning Objectives:

The main objectives of this course are to:

- Introduce the algebraic and order axioms of the real number systems.
- Familiarize the students with the fundamental concepts of real analysis such as countable set, uncountable set, Archimedean property, completeness property, dense property in R.
- Introduce the notion of derivative and study basic properties.
- Establish a relation between a function's behavior (specifically its derivative) and its values over an interval. Specifically Mean value Theorems connect the average rate of change of a function over an interval to its instantaneous rate of change (derivative) at some point within that interval.
- Understand how to evaluate limits that result in indeterminate forms, specifically 0/0 or ∞/∞ by applying L'Hospital's rule.
- Apply the concept of differentiating a function's derivative repeatedly to obtain subsequent derivatives. This includes understanding the notion, finding higher order derivatives for various functions and their applications.
- Understand how the functions Sin x, Cos x, log (1+x) etc. can be represented as infinite polynomials by using Maclaurin's series.
- Equip students with the ability to analyze and understand the geometric properties of curves (envelopes, asymptotes, curvature etc.).

Learning Outcomes:

This course will enable the students to :

- Understand the fundamental algebraic as well as order properties of the real line R.
- Gain knowledge about completeness property of R, Archimedean Principle, Dense property, Countable and Uncountable set, Countability of rational numbers and Uncountability of real numbers.
- Understand the concept of derivative and applying it to solve problems involving rate of change and optimization.
- Relate the behavior of a function to its derivative. Students can realize the importance the geometrical interpretation of Mean Value Theorems and they can apply these theorems in practical problems.
- Develop the ability to recognize and evaluate the Indeterminate forms using various techniques, ultimately leading to a deeper understanding of limits and their applications in Calculus.
- Calculate the second, third and higher order derivatives of various functions including polynomials, trigonometric functions and exponential functions. Students can be able to find out higher derivatives for the product of two or more functions by applying Leibnitz's theorem.
- Find out the expansions of Sinx, Cosx, log(1+x) by using Maclurin's infinite series with remainder after n terms.
- Understand their definitions and geometric interpretation. They should be able to find out asymptotes of curves, envelope of a family of curves, curvature, quadrature of curves and can solve various related problems.

Syllabus:

Real Number Systems:
Algebraic and order axioms of the real number system without construction. Existence of nth roots of positive real numbers. The completeness property of R. Archimedean Principle, Dense property, Existence of nth roots of positive real numbers. Countable and uncountable sets, Countability of rational numbers and unaccountability of real numbers.

Derivatives:
Review of derivative, Intermediate value property for derivatives.

Mean Value Theorems:
Rolle's theorem, Lagrange's Mean Value theorem, Cauchy's mean value theorem and applications.

Indeterminate forms:
L'Hospital's rule and its applications.

Higher order derivatives:
Successive Differentiation, Leibnitz's rule and its applications.

Expansion of functions:
Taylor's and Maclaurin's theorems with different forms of remainder, Maclaurin's series, Maxima and Minima, e^x, $\sin x$, $\cos x$, $\log(1+x)$, $(1+x)^n$.

Envelope, Asymptotes, Curvature, Quadrature, Rectification, Volumes and Surfaces of Revolution.

Books Recommended:

1. S. N. Mukhopadhyay and A. Layek, *Mathematical Analysis:Vol-I*, U. N. Dhar & Sons. Pvt. Ltd., 2nd Edition, 2009.
2. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, Wiley India Pvt. Ltd, 4th Edition, 2021.
3. S. K. Mapa, *Introduction to Real Analysis*, Sarat Book Distributors, Revised 8th Edition, 2021
4. R. K. Ghosh and K. C. Maity, *An introduction to Analysis: Differential Calculus: Part-I*, New Central Book Agency, 13th revised Edition, 2011.
5. S. Ponnusamy, *Foundations of Mathematical Analysis*, Birkhauser, 2011.

6. Corey M. Dunn, *Introduction to Analysis*, CRC Press, 2017.

MJMA02 (Unit I: Analytical Geometry)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	ANALYTICAL GEOMETRY	MJMA 02	2	10	40	50	2	0	0

Learning Objectives:

The main objectives of this course are to:

- Introduce the fundamental concepts of translation and rotation of rectangular axes as well as oblique axes in two dimensional geometry.
- Classify the general equation of second degree (two variables) representing lines, Parabola, Ellipse, Hyperbola and deduce the equation of tangent and normal, poles and polars including reduction to standard form.
- Introduce the concept of Polar coordinates, Polar equation of straight line, Conics, Tangent, Normal, Chord of contact including their formulations and problems.
- Understand the definition of sphere and its equations in different forms including related problems to find out centre, radius, great circle etc.
- Find out analytical equation of cone in different forms and study various problems.
- Introduce the physical concept of conicoids (Ellipsoid, Hyperboloid and Paraboloid) and finding their standard formulas and solve related problems.
- Introduce the concept of generating lines, identifying different types, applying them in problem-solving and representing them mathematically.
- Understand a new coordinate system (Spherical and Cylindrical polar coordinates).

Learning Outcomes:

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

- Understand how coordinate systems can be transformed and how these transformations affect the representation of geometric objects. Students will learn to apply these transformations to simplify the equations.
- Classify the equations, reduce them to their canonical form and understand the properties of the represented geometric figure.
- Learn the concept of tangent, normal, poles and polars to understand the geometric properties of curves and for solving related problems in Calculus and Geometry.
- Understand polar equation of straight line, tangent, normal include plotting points in polar coordinates, converting between coordinate systems, transforming equations.
- Find out the equation of sphere by given conditions. Students should be able to use their knowledge of sphere to understand and appreciate their applications in various fields.

- Derive the equation of cone in different perspectives. Additionally students should be able to solve practical problems involving cones in various contexts.
- Understand the structure of conicoids and they can derive mathematical formulas for the same.
- Learn how straight lines create various 3D shapes. Learning out comes include recognizing ruled surfaces, understanding their generation process and applying this knowledge to peactical examples.
- Gain knowledge about new system of coordinates (Spherical and Cylindrical polar coordinates). Students should be able to convert between coordinates and solving simple problems.

Syllabus:

Two-dimensional Geometry:

Transformation of Axes:
Translation, Rotation, Invariants, Rigid motion, Oblique axes.

General Equation of Second Degree:
Classification of quadratic equations representing lines, Parabola, Ellipse, Hyperbola. Tangent and Normal, Poles and Polars. Normal forms.

Polar equations:
Polar co-ordinates, Polar equation of straight line, Conics, Tangent, Normal, Chord of contact.

Three-dimensional Geometry:
Brief review of direction cosines, direction ratios, plane and straight line.

Sphere:
Equation in different forms, Section of a sphere with a given plane, Section of two spheres. Radical plane and line, Co-axial systems of spheres.

Cone:
Cone with vertex at origin, Condition for general equation of second degree to represent a cone, Right circular cone, Intersection of cone by a plane, Condition for three mutually perpendicular generators.

Conicoids:
Paraboloid, Ellipsoid, Hyperboloid and their tangent planes and normals.

Generating Lines:
Ruled surfaces, Generating lines of hyperboloid of one sheet, Hyperbolic paraboloid, Properties of generators, Condition for a straight line to be a generator of a given conicoid.

Other Co-ordinate Systems:
Spherical polar co-ordinates, cylindrical polar co-ordinates.

Books Recommended:

1. E. H. Askwith, The analytical geometry of the conic sections, Radha Publishing House, Kolkata, 1988.
2. M. C. Chaki, A text book of analytical geometry, Calcutta Publishers, Kolkata.
3. S. L. Loney, The elements of co-ordinate geometry, Macmillan and Company, London.
4. R. J. T. Bell, An elementary treatise on co-ordinate geometry of three dimensions, Macmillan India Ltd.
5. Shanti Narayan, Analytical solid geometry, S. Chand & Co. (Pvt.) Ltd, New Delhi.

MJMA02 (Unit II: Vector & Tensor Calculus)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Vector & Tensor Calculus	MJMA 02	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce the fundamental concepts of vector-valued functions.
- Introduce the notion of differentiation of vector-valued functions leading to the notions of arc-length of a parametrized curve, tangent, normal, directional derivatives, Frenet-Serret formula.
- Introduce line integrals, multiple integrals, Green's theorem, Stokes theorem and Gauss's divergence theorem with applications.
- Introduce the basic contents of tensor calculus.

Learning Outcomes:

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

- Solve problems of Euclidean geometry using techniques of vector calculus.
- Realize the power of tackling geometric problems via vector calculus.
- Calculate surface integral and volume integral.
- Learn how the notion of vector can be generalized to introduce tensor.

Syllabus:

Basic Concepts:

Properties of scalar and vector triple products. Reciprocal system of vectors and their applications.

Vector-valued functions:

Limit and continuity of vector-valued functions. Derivative of a vector function and its properties. Tangent and normal vectors. Serret-Frenet formula. Directional derivative, gradient, divergence, curl, Laplacian and their properties. Applications.

Vector integration:

Introduction to double and triple integrals**,** Line integrals, surface integrals, volume integrals, Green's theorem, Stokes' theorem, Gauss's divergence theorem. Applications.

Tensor Calculus:

Contravariant and Covariant vectors and tensors. Mixed Tensors. Algebra of tensors. Quotient laws. Fundamental and Associate tensors. Christoffel's symbols. Covariant differentiation of vectors and tensors. Riemann-Christoffel tensors.

SEMESTER II

MJMA03 & MJMA04

MJMA03 (Unit I: Linear Algebra over R)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Linear Algebra over R	MJMA03	2	10	40	50	2	0	0

Learning Objectives:
The objectives of this course are to:

- Learn methods for solving system of linear equations over R.
- Characterize the set of all solutions of a consistent system of linear equations.
- Introduce linear span and linear independence, and discuss their relationship with the existence and uniqueness of solutions of a linear system.
- Introduce subspaces of R^n, their basis and dimension.
- Discuss orthogonality of vectors in R^n.
- Introduce notions of eigenvalues and eigenvectors of a matrix, and discuss methods for finding them.

Learning Outcomes:
After completion of this course, students will be able to:

- Solve both homogeneous and nonhomogeneous systems of linear equations.
- Represent the set of all solutions of a consistent system in different forms.
- Characterize geometrically linear independence and linear span.
- Find basis and dimension of the subspace of all solutions of a homogeneous system.
- Visualize orthogonal complement of a subspace.
- Find eigenvalues and eigenvectors of a square matrix.

Syllabus:

Systems of linear equations, homogeneous and non-homogeneous systems. The matrix equation AX=b, row reduction and echelon forms, uniqueness of reduced echelon form. Pivot positions, basic and free variables, rank of a matrix (in terms of unique reduced echelon form) and parametric description of the solution set. Existence and uniqueness theorem for solutions of a system of linear equations.

Vectors in R^n. Vector form of a linear system and the column picture. Question of existence of solutions and linear combination of vectors. Question of uniqueness of solution and linear independence of vectors. Independent subsets. Geometry of linear span and linear independence.

Subspaces of R^n. Existence of basis and dimension of a subspace. Four fundamental subspaces associated with a matrix.
Orthogonality in R^n. Orthogonality of row space and null space of a matrix. Orthogonal complement of a subspace. The dimension of the solution space of AX = 0 and the rank of A.
Inverse of a matrix, equivalent characterizations of invertible matrices.
Eigen values, Eigenvectors and the characteristic equation of a real matrix. Diagonalizability of real matrices.

Books Recommended:

1. Howard Anton and Chris Rorres, Elementary Linear Algebra, 11th Ed., Wiley, 2016.
2. Bernard Kolman and David Hill, Elementary Linear Algebra with Applications, 9th Ed., Pearson, 2019.
3. David C. Lay, Steven R. Lay and Judi J. McDonald Linear Algebra and its Applications, 5th Ed., Pearson, 2023.
4. Gilbert Strang, Linear Algebra and its Applications, 4th Ed., Cengage, 2005.

MJMA03 (Unit II: Analysis II)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	ANALYSIS II	MJMA 03	2	10	40	50	2	0	0

Learning Objectives:

The main objectives of this course are to:

- Introduce (ε-δ)-definition of limit and continuity of a function on real line $\mathbb{R}$ and algebraic properties.
- Introduce the concept of real sequence, bounded sequence, monotone sequence, convergent sequence, limit of a sequence, Cauchy sequence, sub-sequence.
- Familiarize the students the (ε-δ)-definition of limit and continuity of a function of a complex variable and their algebraic properties.
- Introduce the concept of complex sequence, convergent sequence, limit of a sequence, Cauchy sequence, sub-sequence.

Learning Outcomes:

This course will enable the students to:

- Calculate limit of real valued functions defined on subset of $\mathbb{R}$, as well as $\mathbb{C}$ and examine the continuity of the functions including solving related problems.
- Learn to define sequences in $\mathbb{R}$and$\mathbb{C}$, convergent sequences and to find their limits. Characterize bounded sequence, unbounded sequence in $\mathbb{R}$and Cauchy sequence.
- Understand the correspondence between Riemann sphere and complex plane $\mathbb{C}$via stereographic projection and solve related problems.

Syllabus:

Functions of single real variable: Basic properties of limits, Bounded functions, Continuous functions.

Real sequences: Bounded sequences, Monotone sequences, Convergent sequences, Limit of a sequence, Theorem on limits of sequences, Cauchy's limit theorems, Cauchy's sequence and Cauchy's general principle. Sub-sequence, Existence of monotone subsequence, Cluster points, Nested interval theorem, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior.

Functions of a Complex Variable: Limits of Functions, Theorems on Limits, Continuous Functions, Continuity in terms of Real and Imaginary parts.

Complex Sequences: Sequences of complex numbers, Limit and limit points of a sequence, Cauchy's General Principle of convergence. Stereographic projection and extended complex plane.

Books Recommended:

1. R. G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, Wiley India Pvt. Ltd, 4th Edition, 2021.
2. S. K. Mapa, *Introduction to Real Analysis*, Sarat Book Distributors, Revised 8th Edition 2021.
3. R. K. Ghosh and K. C. Maity, *An introduction to Analysis: Differential Calculus: Part-I*, New Central Book Agency, 13th revised Edition, 2011.
4. S. N. Mukhopadhyay and A. Layek, *Mathematical Analysis:Vol-I*, U. N. Dhar & Sons. Pvt. Ltd., 2nd Edition, 2009.
5. B. K. Lahiri, *Complex Analysis*, The World Press Private Limited.
6. Sobhakar Ganguly, *Elements of Complex Analysis*, Academic Publisher, 2020.
7. A. I. Markushevich, *Theory of functions of a Complex Variable*, Prentice Hall, Inc., 2001.

MJMA04: Ordinary Differential Equations I

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major Course	Ordinary Differential Equations I	MJMA04	4	20	80	100	3	1	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce fundamental concepts and classifications of ordinary differential equations, including their formation from physical and geometrical problems.
- Develop skills in solving first order linear and nonlinear ordinary differential equations using different methods.

- Explore different solution techniques for higher order linear differential equations with both constant and variable coefficients.
- Provide theoretical grounding in concepts such as existence, uniqueness, and Wronskian.

Learning Outcomes:

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

- Formulate and classify ordinary differential equations derived from physical, geometrical, and applied phenomena.
- Identify and solve various forms of first order equations, including exact, homogeneous, linear, Bernoulli, and Riccati equations.
- Apply appropriate techniques to determine integrating factors for first order differential equations.
- Use methods to solve nonlinear first order differential equations.
- Analyze and solve higher order linear ordinary differential equations with constant and variable coefficients using symbolic operators and transformation methods.
- Use the method of variation of parameters to solve first order and second order linear differential equations.
- Interpret the geometrical and physical significance of solutions, including singular solutions.

Syllabus:

Basic Concepts:

Definition of ordinary differential equation (ODE), formation of ODEs by elimination of arbitrary constants, formation of ODEs from real-world problems, meaning of the solution of ODEs (geometrical and physical), concept of linear and nonlinear ODEs, concept of initial value problems (IVP) and boundary value problems (BVP) in ODEs, concept of direction field and isocline.

First Order ODEs of first Degree:

Existence and uniqueness theorem for 1st order and higher order differential equations (statement only), general solution and particular solution of 1st order IVP, separable equations and equations reducible to this form, homogeneous equations, nonhomogeneous equations, exact equations and condition for exactness, integrating factor and methods of finding integrating factors, linear equations, Bernoulli equations, equations reducible to 1st order linear equations, solution of 1st order ODE by the variation of parameters method, orthogonal and oblique trajectories, Riccati's equation and the method of solving Riccati's equation.

First Order ODEs of Higher Degree:

Equations solvable for p, equations solvable for x, equations solvable for y, Clairaut's equation, equations reducible to Clairaut's form, Lagrange's Equation, p-discriminant and c-discriminant relations, nodal locus, cuspidal locus, tac Locus, singular solution, geometrical significance of singular solutions.

Higher Order Linear ODEs with Constant Coefficients:

Linearly dependent and independent solutions, Wronskian and its properties, general solution of homogeneous equation of second order, principle of superposition for homogeneous equation, finding particular integrals (P. I.) by symbolic operator D, solution of ordinary differential equations by variation of parameters method.

Higher Order Linear ODEs with Variable Coefficients:

Cauchy-Euler homogeneous equations, method of variation of parameters, criterion of an exact differential equation, linear and nonlinear exact equations, change of dependent variable, reduction to normal form, change of independent variable, reduction of order, factorization of the operators.

Applications:

Applications of first order and second order differential equations to real-world problems in physics, engineering, biology, and other applied fields.

Books Recommended:

1. E. D. Rainville, P. E. Bedient, and R. E. Bedient, Elementary Differential Equations (Pearson).
2. D.G. Zill, A First Course in Differential Equations with Modeling Applications (Cengage).
3. S. L. Ross, Differential Equations, (Wiley).
4. P. R. Ghosh and J. G. Chakraborty, Differential Equations (U. N. Dhar & Sons).
5. R. K. Ghosh and K. C. Maity, An introduction to Differential Equations (New Central).
6. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, (Wiley).
7. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations (McGraw-Hill).
8. H. T. H. Piaggio, Differential Equations (G. Bell & Sons).

SEMESTER III

MJMA05 & MJMA06

MJMA05 (Unit I: Analysis III)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	ANALYSIS III	MJMA05	3	15	60	75	2	1	0

Learning Objectives:

The main objectives of this course are to:

- Introduce deeper properties of continuous function on an interval and the classification of discontinuity and relation with monotone functions.
- Introduce the concept of infinite series, its convergence and various tests for convergence.
- Familiarize the students with the notion of Riemann integration and its properties for different types of functions and also present Riemann-Stieltjes integrals.

- Introduce the concept of functions of bounded variations, improper integrals, Beta and Gamma functions.

Learning Outcomes:

This course will enable the students to:

- Learn to characterize continuous functions and to prove some results analytically in detail and to distinguish the discontinuous functions according to their types and also to understand the difference between continuity and uniform continuity.
- Learn to determine the convergence of different series using various tests and solve related problems.
- Evaluate the Riemann integrals of bounded functions and solve different problems related to integration and characterize functions of bounded variations.
- Test improper integrals for convergence and solve problems associated with Beta and Gamma functions.

Syllabus:

Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Boundedness theorem,

Discontinuous functions, Classification of discontinuities.Monotone functions and its points of discontinuity. Uniform continuity, Sequential criteria for non-uniform continuity, uniform continuity theorem.

Series: Convergence and Divergence, Series of non-negative terms, p-series. Test for convergence: Comparison test, D'Alembert ratio test, Cauchy's root test, Kummer's test, Raabe's test, Logarithmic test, Gauss test. Alternating series: Leibnitz's test, Absolute convergence, Conditional convergence.

Riemann integration: Upper and lower sums, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two definitions, Riemann integrability of monotone and continuous functions and discontinuous functions, Properties of the Riemann integral, Mean value theorems for Riemann integral, Fundamental theorem of Calculus.

Functions of bounded variations, Simple properties, Jordan decomposition theorem.

Riemann-Stieltjes Integral: Definition and Properties, Existence of the integral.

Improper integrals; Convergence and Absolute Convergence, Cauchy's Criterion (Statement only), Comparison tests, Abel's and Dirichlet's tests, Convergence of Beta and Gamma functions.

Books Recommended:

1. W. Rudin, Principles of Mathematical Analysis, TMH, Third Edition, Indian Edition, 2013.
2. T. M. Apostal, Mathematical Analysis, Narosa Book Disributors Pvt. Ltd., 2nd Edition, 2000.
3. S. C. Malik & S. Arora, Mathematical Analysis, New Age International Publishers, 4th Edition, 2010.
4. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Wiley India Pvt. Ltd, 4th Edition, 2021.
5. R.K. Ghosh and K.C. Maity, An introduction to Analysis: Differential Calculus: Part-I, New Central Book Agency, 13th revised Edition, 2011.
6. S. N. Mukhopadhyay and S. Mitra – Mathematical Analysis – Vol-II (U. N. Dhar & Sons. Pvt. Ltd.), 2014.
7. Konrad Knopp, Infinite sequences and series, Dover Publication, 1990.
8. Shanti Narayan, A course of Mathematical Analysis, S. Chand and Co. Ltd., 1st Edition, 2005.
9. S. K. Mapa, Introduction to Real Analysis, Sarat Book Distributors, Revised 8th Edition, 2021.

10. S. Ponnusamy, Foundations of Mathematical Analysis, Birkhauser, 2011

MJMA05 (Unit II: IKS I--Infinite Series in Kerala Mathematics)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	IKS I (Infinite Series in Kerala Mathematics)	MJMA05	1	5	20	25	1	0	0

Learning Objectives:

- Introduce the foundational contributions of the Kerala School to the development of infinite series.
- Understand the derivations and convergence logic presented in the Yuktibhāṣā treatise.
- Demonstrate how Rsine and Rcosine series can approximate π and trigonometric values.
- Explore quadrature and arc-length techniques used in classical Indian astronomy.

Learning Outcomes:

- Explain the structure and derivation of Rsine and Rcosine series from primary Sanskrit–Malayalam sources.
- Analyze the convergence arguments employed in Yuktibhāṣā and compare them with present-day proofs.
- Compute π and selected trigonometric ratios using indigenous infinite-series methods.
- Apply Indian quadrature and arc-length approximations to classical geometric problems.
- Interpret total-variation ideas within cyclic astronomical modelling and link them to modern summation techniques.

Syllabus:

Infinite series from the Kerala School: Rsine and Rcosine series.

Derivations and convergence logic in Yuktibhāṣā.

Approximation of π and trigonometric values using series.

Quadrature and arc-length approximations in Indian astronomy.

Books recommended:

K. V. Sarma & S. S. Vasantha Kumari (trans.), *A Rational Refutation (Yuktibhāṣā) of Jyesthadeva*, Springer, 2008.

P. P. Divakaran, *The Mathematics of India: Concepts and Connections*, Springer, 2018.

C. K. Raju, *Cultural Foundations of Mathematics*, Pearson Longman, 2007.

T. K. Puttaswamy, *Mathematical Achievements of Pre-Modern Indian Mathematicians*, Elsevier, 2012.

UGC Sourcebook: *Kerala School of Mathematics and Astronomy*

MJMA06 (Unit I: Ordinary Differential Equations II)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Ordinary Differential Equations II	MJMA 06	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Determine the relationships between multiple dependent variables and how they change concerning an independent variable (usually time) when solving simultaneous linear differential equations.
- Verify the functions or relationships between variables that make the equation true when substituted into the total differential equations.
- Find out series solutions of linear ordinary differential equations, especially those with variable coefficients or those that cannot be solved using elementary functions, by expressing the solution as an infinite power series.
- Include learning about special functions like Bessel and Legendre functions along with their recurrence relations, orthogonal properties, and integral representations.
- Provide theoretical grounding in concepts with the solutions of n-th order homogeneous and non-homogeneous linear differential equations, as well as Wronskian.
- Focus on the application of *knowledge and skills as o*rdinary differential equations play a crucial role in various aspects of machine learning (ML), artificial intelligence (AI), and networking. They are foundational in modelling the dynamical systems, particularly those involving continuous change over time.

Learning Outcomes:

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

- Classify ordinary and singular points of the differential equations and concerned series solutions.
- Identify and solve total differential equations with various analytical methods.
- Explanation of solution of various special functions and their mathematical properties.
- Verify the linear independence of solutions as fundamental set to the differential equations through Wronskian approach.
- Analyze and solve the system of differential equations with eigenvalue-eigenvector method.

Syllabus:

Simultaneous Linear Differential Equations:
Methods of solving simultaneous equations of Type I. Methods of solving simultaneous equations of Type II. Geometrical Interpretation.

Total Differential Equations:
Conditions for integrability. Methods of solving total differential equations. Geometrical Interpretation.

Series Solution of ODEs and Special Functions:
Ordinary point, Singular point, Series solutions (Power series, Frobenius method), Series solution of Legendre's equation and Bessel's equation.
Legendre functions. Legendre polynomials and their zeros. Rodrigues' formula. Generating function. Legendre coefficients. Recurrence relations. Orthogonality.
Bessel functions. Bessel functions of first kind and of second kind of integer order. Generating function. Identities. Recurrence relations. Orthogonality. Bessel integral formula.

Systems of Linear Differential Equations:
Types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two equations in two unknown functions. Theory of n-th order homogeneous linear differential equations. Theory of n-th order non-homogeneous linear differential equations. Wronskian, Abel-Liouville formula.

Books Recommended:

1. Differential Equations, S. L. Ross, Wiley, 2007
2. Special Functions for Scientists and Engineers, W.W. Bell, Dover, 2004.
3. Special Functions & Their Applications, N. N. Lebedev, R. A. Silverman, Dover, 2003.
4. Introduction to Bessel Functions, F. Bowman, Dover, 2003.
5. An Introduction to Special Functions, C. Viola, Springer, 2016.
6. Special Functions, Z. X. Wang, D. R. Guo, World Scientific, 1989.
7. Elementary Differential Equations and Boundary Value Problems, W. E. Boyce and R. C. DiPrima, Wiley, 2008.
8. Differential Equations and Boundary Value Problems: Computing and Modeling, C. H. Edwards and D. E. Penny, Pearson Education India, 2016.

MJMA06 (Unit II: Dynamics of a Particle)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Dynamics of a Particle	MJMA 06	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to :

- understand how forces affect the motion of a particle, with a focus on understanding the relationship between forces, mass, and motion.

- mastering concepts like kinematics, Newton's laws of motion, work and energy, and momentum.

Learning Outcomes:

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

- mastering problem-solving in one and two dimensions, understanding concepts like terminal speed and planetary motion. Furthermore, it provides a foundation for understanding more complex systems and phenomena, such as rigid dynamics.
- apply these principles to model and predict the behavior of physical systems involving particles.

Syllabus:

Fundamental definitions and principles.
Motion in a straight line, Harmonic oscillator, Damped forced oscillation.
Motion in a plane: Tangential and Normal Accelerations, Radial and Cross-radial accelerations, Path for a given law of force.
Motion of a particle under central forces, Planetary motion.
Motion in a resisting medium.

Books Recommended:

1. S. L. Loney, An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies, McGraw-Hill, 2018.

2. F. Chorlton, A Text Book of Dynamics, (John Wiley & Sons, New York) ,1983.

3. A. S. Ramsey, Dynamics (Vols. I & II), Cambridge University Press,2009.

4. M. Spiegel, Theory and Problems of Theoretical Mechanics, Schaum's Outline Series,2021.

5. J. G. Chakravorty & P. R. Ghosh. Advanced Analytical Dynamics, U. N. Dhar & Sons Pvt. Ltd., 2017.

SEMESTER IV

MJMA07, MJMA08, MJMA09, MJMA10

MJMA07: Quotients and Homomorphisms

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Quotients and Homomorphisms	MJMA07	4	20	80	100	3	1	0

Learning Objectives:

The objectives of this course are to:

- Introduce the notion of cosets, and discuss properties of cosets leading to the Lagrange's Theorem for finite groups.
- Introduce normal subgroups and construct quotient groups.
- Study the notion of group homomorphisms and isomorphisms.
- State and prove the three isomorphism theorems of groups.
- Classify groups of small order up to isomorphism.
- Introduce the notions of rings, integral domains and fields, and discuss their basic properties.
- Study ideals and quotient rings.
- Introduce ring homomorphisms and isomorphism theorems of rings.

Learning Outcomes:

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

- Apply Lagrange's Theorem for finite groups to classify finite groups.
- Relate problems arising from number theory with group theory.
- Construct and identify both quotient groups and rings.
- Characterize completely each group of order 4 or of order 6.
- Apply the first isomorphism theorem both in groups and rings.

Syllabus:

Cosets and normal subgroups:

Properties of cosets, Lagrange's theorem and its consequences. Index of a subgroup, multiplicative property of index. External direct product of groups; examples and basic properties. Product of cyclic groups. Normal subgroups and factor groups.

Homomorphisms of groups:

Group homomorphisms, properties of homomorphisms. Isomorphisms, definition and examples. Properties of isomorphisms. Cayley's theorem. Isomorphism classes of cyclic groups and groups up to order 6. Isomorphism theorems and the correspondence theorem. Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups.

Rings and ideals:

Definition and examples of rings, properties of rings, subrings. Integral domains and fields, characteristic of a ring. Ideal, operations on ideals and ideal generated by a subset of a ring. Factor rings; the chinese remainder theorem. Prime and maximal ideals.

Homomorphisms of rings:

Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems and the correspondence theorem. The field of quotients.

Books Recommended:

1. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
2. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., Wiley, 2011.
3. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2013.
4. Joseph A. Gallian, Contemporary Abstract Algebra, 9th Ed., Cengage, 2020.
5. I. N. Herstein, Topics in Algebra, 2nd Ed., Wiley, 2006.
6. Charles C. Pinter, A Book of Abstract Algebra, 2nd Ed., Dover, 2010.
7. Vivek Sahai and Vikas Bist, Algebra, 4th Ed., Alpha Science, 2018.
8. M. K. Sen, Shamik Ghosh, Parthasarathi Mukhopadhyay and Sunil Kumar Maity, Topics in Abstract Algbera, 4th Ed., Universities Press, 2022.

MJMA08: Analysis IV

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Analysis IV	MJMA 08	4	20	80	100	3	1	0

Learning Objectives:

The primary objectives of this course are to:

- gain the knowledge about sequence and series of functions and their basic properties
- gain the basic concept of power series, radius of convergence of a power series and basic properties of a power series.
- gain the knowledge about limit, continuity, differentiability of a function of several real variables.

Learning Outcomes:

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

- compute radius convergence of a power series, their integrability and differentiability criterion
- examine existence of limit, continuity and differentiability of a function of several real variables.
- examine pointwise and uniform convergence of sequence of functions and their interrelationship.

Syllabus:

Sequence and Series of functions: Pointwise and uniform convergence, Theorems on continuity, derivability and integrability of the limit function and sum function, Cauchy criterion for uniform convergence and Weierstrass M-Test.
Power series: Radius of convergence, Cauchy-Hadamard Theorem, Differentiation and integration of power series, Abel's Theorem, Real analytic function, Weierstrass Approximation Theorem.
Functions of Several Variables: Limit and Continuity, Partial derivatives, Homogeneous Functions and Euler's Theorem, Differentiability, Chain rules, Total differentials, Schwarz's and Young's theorems, Theorem of existence and uniqueness of implicit functions, Jacobians and their simple properties, Statement of inversion theorem, Mean value theorem, Taylor's theorem, Maxima, Minima and saddle points, Lagrange's multiplier method, Differentiation under integral sign, Leibnitz rule.
Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions. Change of variables in double integrals and triple integrals, Volume by triple integrals, cylindrical and spherical co-ordinates**.**

Books Recommended:

1. Konrad Knopp, *Theory and application of Infinite series*, Dover Publication, 1990.
2. S. K. Mapa, *Introduction to Real Analysis*, Sarat Book Distributors, Revised 8th Edition, 2021.
3. R. R. Goldberg, *Methods of Real Analysis*, Oxford and IBH Publishing Co. Pvt. Ltd, 2021.

4. P. C. Bhakta, *A Course of Real analysis*, Sarat Book Distributors, 2014.
5. David. V. Widder, *Advanced Calculus*, Prentice Hall of India Private Limited.
6. S. C. Malik and Savita Arora, *Mathematical Analysis*, New Age International (P) Ltd. Publishers, 2005.
7. K. C. Maity and R. K. Ghosh, *An introduction to Analysis, Integral Calculus*, Books and Allied (P) Ltd, 2013.
8. S. N. Mukhopadhyay and S. Mitra – *Mathematical Analysis* – Vol-II (U. N. Dhar & Sons. Pvt. Ltd.), 2014.
9. S. Ponnusamy, *Foundations of Mathematical Analysis*, Birkhauser, 2011.

MJMA 09 (Unit I: Partial Differential Equations)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Partial Differential Equations	MJMA 09	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce fundamental concepts and classifications of partial differential equations, including their formation from real-world problems.
- Formulate mathematically and solve problems involving functions of multiple variables, particularly those related to rates of change and relationships between quantities that vary across space and time.
- Explore different solution techniques for first and second order partial differential equations with both constant and variable coefficients.
- Study the notions of relationship between complete, particular, general and singular solutions.
- Focus on the application of knowledge and skills as partial differential equations are increasingly important in machine learning (ML), artificial intelligence (AI), and networking, offering a powerful framework for modeling complex phenomena and enhancing algorithm design.

Learning Outcomes:

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

- Classify linear, semi-linear, quasi-linear and non-linear partial differential equations.
- Carry out the solution of first order linear, semi-linear, quasi-linear partial differential equations using Lagrange's method and first order non-linear partial differential equations using Charpit's method.
- Evaluate integral surface of first order non-linear partial differential equations directly without evaluating complete integral through Cauchy's method of characteristic.
- Realization of Cauchy-Euler method to solve second order linear partial differential equations with variable coefficients.
- Interpret the geometric and physical significance of solutions, including singular solutions.

Syllabus:

First Order PDEs:
Introduction. Formation of PDE and geometrical interpretation. Genesis of first order PDEs. Classification of integrals. Canonical forms of first order linear equations. Lagrange's method to solve quasi-linear PDEs. Method of separation of variables for solving first order PDEs. Cauchy's problem for first order PDEs.
Compatible systems of first order PDEs. Charpit's method to solve first order nonlinear PDEs. Integral surface through a given curve. Monge cone, Characteristic strip. Cauchy's method of characteristic.
Second Order PDEs:
Second order PDEs with constant coefficients. Simple techniques to solve second order PDEs with variable coefficients.
Applications leading to PDEs: Well-posed PDEs. First-order PDEs. Integral surface through a given curve. Monge cone. Characteristic strip. Cauchy's method of characteristic.
Second-order PDEs with constant and variable coefficients: Monge's method of solution.

Books Recommended:
1. Partial Differential Equations: An Introduction, W.A. Strauss, John Wiley & Sons Ltd., 2007.
2. An Elementary Course in Partial Differential Equations, T. Amarnath, Narosa, 2003.
3. Partial Differential Equations, F. Prasad and R. Ravindran, New Age International Publishers, 2022.
4. Elements of Partial Differential Equations, I. N. Sneddon, Tata McGraw-Hill, 2006.
5. Linear Partial Differential Equations for Scientists and Engineers, Tyn Myint-U, L. Debnath Birkhäuser, 2017.
6. Nonlinear Partial Differential Equations for Scientists and Engineers, L. Debnath, Birkhäuser, 2012.

MJMA09 (Unit II: Dynamics of a Rigid Body)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Dynamics of a Rigid Body	MJMA09	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to :

- understand and predict the motion of objects, both translational and rotational, that maintain a constant shape under the influence of forces and torques.
- apply principles of mechanics, specifically D'Alembert's principle and energy and momentum conservation, to analyse the behavior of rigid bodies in various scenarios.

Learning Outcomes:

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

- have a strong foundation in classical mechanics, enabling to calculate resultants of forces and moments and determine their effects on rigid bodies
- analyse, predict, and manipulate the motion of rigid objects in various applications ranging from engineering design to understanding natural phenomena.

Syllabus:

Kinetics of a rigid body: Moments and products of inertia of a rigid body; Simple cases of moments of inertia; Momental ellipsoid; Principal axes, Examples.
Motion of a rigid body: D'Alembert's principles; General equations of motion of a rigid body in space.
Motion about a fixed axis, Examples; Compound pendulum; Motion about a fixed axis under repulsive forces; Centre of percussion.
Motion in two dimensions: Motion in a plane under finite forces; Kinetic energy, moment of a force and angular momentum.

Books Recommended:

1. S. L. Loney, An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies, McGraw-Hill,2018
2. F. Chorlton, A Text Book of Dynamics, John Wiley & Sons, New York, 2nd Edition, 1983.
3. A. S. Ramsey, Dynamics (Vols. I & II), Cambridge University Press, 2003.
4. M. Spiegel, Theory and Problems of Theoretical Mechanics, Schaum's Outline Series,2021.

5. J. G. Chakravorty & P. R. Ghosh. Advanced Analytical Dynamics, U. N. Dhar & Sons Pvt. Ltd,2017.

MJMA10 (Unit I: Mathematical Probability & Statistics)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Mathematical probability & statistics	MJMA10	3	15	60	75	3	0	0

Learning Objectives:

The primary objective of this course is to equip students with a strong foundation in the theoretical aspects of analytical and problem solving skills in probability theory and statistical methods, preparing them for career paths in diverse fields. Specifically, the course focuses on

- Students will learn the basic concepts of probability, including the probability distributions (continuous and discrete), mathematical expectations, and Tchebycheff's inequality with examples. The course also aims to develop students' ability to understand and apply statistical inference techniques to estimate various population parameters and draw conclusions about the populations based on sample data.
- The course will feature the practical applications of mathematical probability and statistics in various fields, including science and engineering, everyday life (e.g., weather forecasting, decision making, etc.), and computer science (e.g., machine learning, artificial intelligence, and networking).

- Students will be able to solve real-world problems in various domains, including science and engineering, social sciences, and finance. They will also develop skills in descriptive statistics, testing of hypothesis, and other statistical methods to analyze and interpret data effectively.
- Having proficiency in programming languages like Python, students will be able to analyze data, identify patterns, and solve various complex problems using mathematical and statistical methods.

Learning Outcomes:

Upon successful completion of this course, students will have

- Strong analytical and problem-solving skills.
- Ability to analyze data and interpret them.
- Intertwined concept for probability and statistical modelling

Syllabus:

Mathematical Probability:

Preliminaries: Axiomatic definition of probability; General addition and multiplication rules; Stochastic independence of events. Binomial law, Poisson trials, Markov chains.

Probability distributions: Random variables: Continuous and discrete; Distribution functions and their properties in one and two dimensions. Conditional distributions. Transformation of random variables in two dimensions.

Mathematical expectations: Mean, variance, and moments of different distributions; Moment generating function and Characteristic functions. Expectation for bivariate distributions: Covariance and correlation coefficient of two random variables. Regression lines.

Convergence in probability: Tchebycheff's inequality and convergence in probability. Law of large numbers and Bernoulli's theorem.

Mathematical Statistics:

Preliminaries: Population and random sample; Distribution of the sample. Sample characteristics.

Sampling distribution: Sampling distribution of a statistic; Exact sampling distribution of the Normal population.

Statistical Inference I: Estimation of parameters--Consistent and Unbiased; Point estimation by the method of maximum likelihood; Interval estimation for Normal population parameters.

Statistical Inference II: Testing of hypothesis--Simple and Composite; Two types of errors; Critical region. Methods of finding tests: Likelihood ratio testing. Best critical region; Neyman-Pearson theorem; Application to Normal population.

Books Recommended:

1. A. Gupta, Groundwork of Mathematical Probability and Statistics, Academic Press.

2. W. Feller, An Introduction to Probability Theory and its Applications, Vols. I and II, Wiley Eastern.

3. J. V. Uspensky, Introduction to Probability, Tata McGraw-Hill

4. B.V. Gnedenko, The Theory of Probability, Tata McGraw-Hill.

5. R. V. Hogg and A. T. Craig, Introduction to Mathematical Statistics, New York: Macmillan.

6. S. C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.

MJMA10 (Unit II: Mahalanobis Distance)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	IKS II (Mahalanobis Distance)	MJMA10	1	5	20	25	1	0	0

Learning objectives:

The primary objectives of this course are to:

- Understand and interpret the formula.
- Understand the key difference between Mahalanobis and Euclidean distances.
- Learn comparison across different datasets and variables.

Learning Outcomes:

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

- Identify outliers in multivariate datasets.
- Understand how Mahalanobis distance can be used as a similarity measure in clustering and classification algorithms.
- Apply to multivariate analysis, particularly in comparing groups and assessing differences.

Syllabus:

Foundations of Statistics and Data Structure: Central tendency in data-mean, median, mode, standard deviation, covariance and correlation, analyses of variance and covariance.

Mahalanobis Distance (MD): Euclidean distances in 2D and 3D; Covariance Matrix, Construction and inversion of a covariance matrix. Key concepts of MD, Properties of MD—Scale invariance, Distance from the mean, Accounts for covariance, Relationship to Euclidean distance. Multivariate Normal Distribution and MD.

Applications of MD: Outlier Detection, Classification and clustering, Medical diagnosis and image processing, and Anthropology.

Books Recommended

1. P. C. Mahalanobis, On the Generalized Distance in Statistics. Proceedings of the National Institute of Science of India, 2, 49-55 (1936).
2. Richard A. Johnson and Dean W. Wichern, Applied Multivariate Statistical Analysis, Springer, Sixth Edition, Pearson Prentice Hall 2007.
3. Bryan F. J. Manly and Jorge A. Navarro Alberto, Multivariate Statistical Methods: A Primer; Fourth Edition, CRC Press 2016.

SEMESTER V

MJMA11, MJMA12, MJMA13

MJMA11: Linear Algebra

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Linear Algebra	MJMA11	4	20	80	100	3	1	0

Learning Objectives:

The objectives of this course are to:

- Introduce vector spaces over an arbitrary field, their subspaces, and the notions of basis and dimension.
- Study linear transformations and their basic properties.
- Develop the notion of matrix representations of a linear transformation.
- Study change of coordinate matrix and characterize relationship among the matrix representations of a linear transformation.
- Characterize dual spaces and develop the notion of reflexivity of finite dimensional vector spaces.
- Develop the notion of transpose of a linear transformation and discuss its relationship with the notion of transpose of a matrix.
- Characterize the determinant function.

Learning Outcomes:

By the end of the course, students will be able to:

- Determine bases and the dimension of an arbitrary finite dimensional subspace.
- Compute kernel and other parameters of a linear transformation.
- Represent a linear transformation as a matrix over F.
- Use matrix representations to find rank, trace, and determinant of a linear transformation.
- Compute transpose of linear maps and annihilator of a subspace.
- Realize governing axioms of the determinant function.

Syllabus:

Vector spaces, subspaces, algebra of subspaces, direct sum of subspaces, quotient spaces. Linear combination of vectors, linear span. Linear independence. Basis and dimension, dimension of subspaces. Coordinates; change of coordinate matrices.

Row rank and column rank of a matrix; their equivalence. Rank of a matrix; properties of rank. Full rank factorization and it's consequences. Rank inequalities.

Linear transformations. Algebra of linear transformations. Isomorphisms. Projections, their sum, difference and product.

Matrix representations of a linear transformation; similarity of matrix representations. Rank of a linear transformation and its matrix representation. Determinant and trace of a linear transformation.

Linear functionals. Dual spaces, dual basis. Double dual, reflexivity of finite dimensional vector spaces. Transpose of a linear transformation and its matrix in the dual basis. Annihilator of a subspace.

Determinant functions; their existence and uniqueness. Properties of determinant. Determinant and rank of a matrix.

Books Recommended:

1. Sheldon Axler, Linear Algebra Done Right, 3rd Ed., Springer, 2014.
2. R. B. Bapat, Linear Algebra and Linear Models, 3rd Ed., Springer, 2012.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 5th Ed., Pearson, 2022.
4. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Pearson, 2015.
5. Jin Ho Kwak and Sungpyo Hong, Linear Algebra, 2nd Ed., Birkhauser, 2004.
6. Vivek Sahai and Vikas Bist, Linear Algebra, 2nd Ed., Narosa, 2013.
7. Helene Shapiro, Linear Algebra and Matrices, American Mathematical Society, 2015.
8. Gilbert Strang, Introduction to Linear Algebra, 6th Ed., Wellesley-Cambridge Press, 2023.
9. Fuzhen Zhang, Matrix Theory: Basic Results and Techniques, 2nd Ed., Springer, 2011.

MJMA12: Analysis V

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Analysis V	MJMA12	4	20	80	100	3	1	0

Learning Objectives:

- Provide a foundation in the construction of the real number system using axiomatic and constructive methods.
- Understand set theory concepts such as cardinality, axiom of choice, and Cantor set.
- Equip students with the theory and application of Fourier series.
- Introduce foundational topological concepts such as open and closed sets, compactness,
- Learn the basics of Lebesgue measure and measurable sets on the real line.

Learning Outcomes:

- Construct real number systems and understand completeness and cardinality concepts.
- Analyze the structure and properties of open and closed sets in metric spaces.
- Develop Fourier series for functions and understand convergence results.
- Apply Lebesgue outer measure concepts to identify measurable and non-measurable sets.

Syllabus:

Construction of Real Number System:

Assuming $\mathbb{N}$ and induction, construction of $\mathbb{Z}$, $\mathbb{Q}$ and the Cauchy construction of $\mathbb{R}$; Cantor–Dedekind theorem; Topological Concepts; Open sets, closed sets, neighbourhood of a point, limit points;

Closure and interior of a set; Structure of open sets, open covering, Lindelöf covering theorem; Heine–Borel theorem and its converse.

Fourier Series: Determination of Fourier coefficients; Convergence of Fourier series; Dirichlet's kernel, Parseval's theorem; Weierstrass approximation theorem for trigonometric polynomial; Sine and cosine series.

Set Theory: Axiom of choice, cardinal number, cardinal arithmetic; Schröder–Bernstein theorem; Cardinality of real numbers and natural numbers.

Lebesgue Measure:

Outer measure of a set and its properties; Measurable sets and Lebesgue measure; Properties of measurable sets, Borel sets; Existence of non-measurable sets; Cantor sets.

Books Recommended:

1. S. C. Malik and Savita Arora, Mathematical Analysis, New Age International (P) Ltd. Publishers, 2005.
2. S. K. Mapa, Introduction to Real Analysis, Sarat Book Distributors, Revised 8th Edition, 2021.
3. R. R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd, 2021.
4. Soma Sundaram and B. Choudhury, A first Course in Mathematical Analysis, Norosa Publishing House, 1996.
5. R. G. Bertle and D. R. Sherbert, Introduction to Real Analysis, John Wiley & Sons, Inc.
6. H. H. Sohrab, Basic Real Analysis, Birkhauser, 2003.
7. P. K. Jain, V. P. Gupta, P. Jain, Lebesgue Measure and Integration, 3rd Edition, New Age International Publishers, 2019.
8. S. N. Mukhopadhyay & Subhasis Ray, Measure and Integration: an Introduction, Springer 2025.

MJMA13: (Unit I: Mathematical Modelling)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Mathematical Modelling	MJMA 13	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- How a real world problem is modeled by using Physical laws.
- How a physical model is converted into mathematical models.
- The importance of differential equations in math modelling.
- To understand the birth of ODEs and PDEs.

Learning Outcomes:

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

- Classify mathematical models.
- Handle Deterministic and Stochastic models.
- Understand Limitations of Mathematical Modelling.
- Can obtain the mathematical modelling from real world problems.

Syllabus:

Introduction, Emergence of Mathematical Modelling on simple situations; Basic steps of Mathematical Modelling - its needs; Process / technique of Mathematical Modelling; Some characteristics of Mathematical Models; Importance of the usage of mathematical models over physical models; Classification of mathematical models; Deterministic and Stochastic models and their distinctive features with illustrations; Limitations of Mathematical Modelling.

(1) Mathematical models in first order ordinary differential equations (ODEs) and partial differential equations (PDEs)
(2) Mathematical models in second order ODEs and PDEs
(3) Mathematical models in a system of linear ODEs and PDEs related to physical and biological systems.

Books Recommended:

1. Mathematical Models, Mechanical Vibrations, Population Dynamics, and Traffic Flow: An Introduction to Applied Mathematics, Richard Haberman, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1977.
2. Introduction to Differential Equations with Dynamical System, Stephen L Campbell and Richard Haberman, Princeton University Press, 2008.
3. Concept of Mathematical Modeling, W. Meyer, McGraw-Hill, New York, 1994.
4. Mathematics for Dynamic Modeling, E. Beltrami, Academic Press, Orlando, Florida, 1987.
5. Mathematical Modeling with case Studies, A Differential Equation Approach using Maple and MATLAB, Belinda Barnes and Glenn R. Fulford, Taylor and Francis Group, 2009.
6. Differential Equations and Boundary Value Problems: Computing and Modeling, C. H. Edwards and D. E. Penny, Pearson Education India, 2005.
7. Mathematical Biology, J. D. Murray, Springer-Verlag, Berlin, 1989.
8. Elements of Mathematical Ecology, M. Kot, Cambridge University Press, 2003.
9. Dynamical Systems in Population Biology, X.-Q. Zhao, Canadian Mathematical Society, 2017.
10. Mathematical Models in Biology & Medicine, J. N. Kapur, East West Press Pvt. Ltd., 1985.
11. Differential Equations and Dynamical Systems, L. Perko, Springer, 2001.

MJMA13: (Unit II: Dynamical Systems)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Dynamical Systems	MJMA13	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand Nonlinear Systems
- Understand Oscillations in dynamical systems
- Understand Conjugacy of Maps
- Understand Chaos in dynamical systems

Learning Outcomes:

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

- Solve Problems related to Nonlinear Systems
- Solve Problems related to Oscillations in dynamical systems
- Solve Problems related to Conjugacy of Maps
- Solve Problems related to Chaos in dynamical systems

Syllabus:

Continuous Dynamical Systems:
Nonlinear Systems: Linearization of Non-linear Systems, Limitations, Hartman–Grobman Theorem, Local Stability, Global Stability, Lyapunov Function, Lyapunov Theorem on Stability, LaSalle Invariance Principle. Oscillations: Limit Set, Attractors, Periodic Orbits, Limit Cycle, Poincare-Bendixson Theorem, Bendixson-Dulac Criterion.

Discrete Dynamical Systems:
Maps and Flows, Composition of Maps, Orbits, Phase Portrait, Fixed Points, Stable and Unstable Fixed Points, Basin of Attraction and Basin Boundary, Linear Stability Analysis, Cobweb Diagram, Periodic Points, Periodic Cycles, Stability of Periodic Point and Periodic Cycle, Hyperbolic Points, Non-Hyperbolic Points, Schwarzian Derivative.

Some Maps: Tent Map, Logistic Map, Dynamics of Quadratic Maps, Shift Map, Baker's Map, Circle Map, Henon Map, Smale Horseshoe Map.

Conjugacy of Maps: Conjugacy, Topological semi-conjugacy, Homeomorphism, Topological conjugacy, Conjugacy between different maps.

Chaos: Sensitive Dependence on Initial Conditions (SDIC), Sarkovskii's Theorem, Period-Three Implies Chaos for 1-D Maps. Some Chaotic Maps, Universal sequence, Feigenbaum Number, Poincaré Section, Lyapunov Exponents, Routes of Chaos, Some Examples of Chaos.

Books Recommended:

1. S. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics,Biology, Chemistry, And Engineering, Hachette, 2014.
2. G. C. Layek, An Introduction to Dynamical Systems, Springer, 2015.
3. P. Glendinning, Stability, Instability and Chaos, Cambridge, 1994.
4. S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer, 1996.
5. M. W. Hirsch, S. Smale, R. L. Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos, Academic Press, 2012.
6. R. A. Holmgren, A First Course in Discrete Dynamical Systems, Springer, 1996.
7. J. Hale and H. Koack, Dynamics and Bifurcations, Springer, 2012.

SEMESTER VI

MJMA14, MJMA15, MJMA16

MJMA14: Factorizations and Canonical Forms

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	**Factorizations and Canonical Forms**	MJMA14	4	20	80	100	3	1	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce polynomial rings and study their basic properties.
- Generalize notions of divisibility, factorization, and irreducibility in integral domains.
- Study Euclidean domains, PIDs, UFDs, and their relevance to polynomial factorization.
- Learn key theorems like Gauss's theorem, Eisenstein's criterion for irreducibility, the Chinese Remainder Theorem, etc.
- Introduce and study eigenvalues and eigenvectors of matrices as well as of linear operators.
- Characterize invariant subspaces and prove Cayley-Hamilton theorem.
- Study diagonalizability of matrices and linear operators and their equivalent conditions.
- Study Jordan canonical form of complex matrices and parameters of this form.

Learning Outcomes:

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

- Apply the division algorithm and identify units in polynomial rings.
- Distinguish between prime and irreducible elements and classify rings as EDs, PIDs, or UFDs.
- Factorize polynomials in $Z[x]$, test for irreducibility, and use Eisenstein's criterion.
- Apply Gauss's theorem and the Chinese Remainder Theorem in polynomial rings over fields
- Find eigenvalues and eigenvectors of a linear operator.
- Test diagonalizability of a matrix and a linear operator.
- Reduce diagonalizable matrices and linear operators to their diagonal form.
- Reduce reducible matrices to their JCF.
- Find parameters of a reducible matrix related to JCF.

Syllabus:

Polynomial rings over commutative rings. The division algorithm for polynomials and consequences. Units in a polynomial ring.
Divisibility in integral domain, prime and irreducible elements. Euclidean domain, principal ideal domain and unique factorization domain; greatest common divisor in principal ideal domains and unique factorization domains. The ring of Gaussian integers.
Factorization of polynomials, Gauss's theorem. Unique factorization in $Z[x]$. Irreducibility tests for polynomials, Eisenstein's criterion. The Chinese remainder theorem in the polynomial rings over fields.
Eigen values and eigenvectors of a matrix, characteristic polynomial. Eigen spaces and diagonalizability of a matrix. Eigen values, eigenvectors and the characteristic polynomial of a linear operator. Invariant subspaces and the Cayley-Hamilton theorem.
Diagonal forms, minimal polynomials. Invariant direct sum and the primary decomposition theorem. Equivalent characterizations of diagonalizability. The spectral theorem for the diagonalizable linear operators.
Jordan canonical forms. Generalized eigen spaces and the fundamental theorem of linear operators. Nilpotent operators, Weyr and segre characteristics of a nilpotent complex matrix. Invariants of a nilpotent operator, uniqueness of the invariants. Jordan canonical form of a general matrix. Similarity of matrices and Jordan canonical forms. Reduction of real and complex matrices to Jordan canonical form.

Books Recommended:

1. Michael Artin, Algebra, 2nd Ed., Pearson, 2011.
2. Sheldon Axler, Linear Algebra Done Right, 3rd Ed., Springer, 2014.
3. R. B. Bapat, Linear Algebra and Linear Models, 3rd Ed., Springer, 2012.
4. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., Wiley, 2011.
5. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2013.
6. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 5th Ed., Pearson, 2022.
7. Joseph A. Gallian, Contemporary Abstract Algebra, 9th Ed., Cengage, 2020.
8. I. N. Herstein, Topics in Algebra, 2nd Ed., Wiley, 2006.
9. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Pearson, 2015.
10. Jin Ho Kwak and Sungpyo Hong, Linear Algebra, 2nd Ed., Birkhauser, 2004.
11. Charles C. Pinter, A Book of Abstract Algebra, 2nd Ed., Dover, 2010.
12. Vivek Sahai and Vikas Bist, Algebra, 4th Ed., Alpha Science, 2018.
13. Vivek Sahai and Vikas Bist, Linear Algebra, 2nd Ed., Narosa, 2013.
14. M. K. Sen, Shamik Ghosh, Parthasarathi Mukhopadhyay and Sunil Kumar Maity, Topics in Abstract Algbera, 4th Ed., Universities Press, 2022.
15. Helene Shapiro, Linear Algebra and Matrices, American Mathematical Society, 2015.
16. Gilbert Strang, Introduction to Linear Algebra, 6th Ed., Wellesley-Cambridge Press, 2023.
17. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 5th Ed., Pearson, 2022.

MJMA15 (Unit I: Analysis VI-- Complex Analysis I**)**

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Complex Analysis I	MJMA15	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce basic concepts of complex differentiability of functions, Cauchy-Riemann equations; analytic functions and harmonic functions and their relation and get skilled in solving related problems.
- Familiarize the students with infinite series and power series and its radius, region of convergence; study bilinear transformations, cross ratio and their relation etc.
- Provide the notion of complex integration and study some famous pivotal results and their applications.

Learning Outcomes

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

- Understand the difference between differentiable and analytic functions and identify functions according to these notions.
- Develop the skill to construct analytic functions from given harmonic functions.
- Apply the known results to find radius of convergence of power series, determine a specific bilinear transformation under given conditions and also find images of some geometric object under a transformation using orientation principle.
- Integrate a complex function along contours, learn techniques to apply them to prove important results and solve typical problems.

Syllabus:

Differentiability of Functions: Definition and Examples, The Cauchy-Riemann Equations, Sufficient conditions for differentiability, Cauchy-Riemann equations in polar form.
Analytic Functions: Definition and examples, Harmonic functions, Conjugate harmonic functions, Construction of an analytic function whose real part is given (Related theorem is to be assumed).

Infinite Series: Series of complex numbers, Absolutely Convergent Series, Power Series, Radius of convergence, Cauchy-Hadamard theorem (Statement only).

Bilinear Transformations: Definition, Cross ratio, Fixed points of a bilinear transformation, Normal form of a bilinear transformation, Inverse points, Circles, Orientation principle.
Definite integrals of functions. Contours, Contour integrals and its examples, Upper bounds for moduli of contour integrals. Cauchy-Goursat theorem (Statement only), Cauchy integral formula. Derivatives of Cauchy integral formula, Liouville's theorem and the fundamental theorem of algebra.

Books Recommended:

1. B. K. Lahiri, Complex Analysis, The World Press Private Limited.
2. R. V. Churchil and J. W. Brown, Complex Variables and Applications, McGraw-Hill, New York, 2013.
3. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 2005.
4. Sobhakar Ganguly, Elements of Complex Analysis, Academic Publisher, 2020.
5. E. T. Copson, An introduction to the theory of functions of a Complex Variable, Oxford University Press, 1970.
6. L. V. Ahlfors, Complex Analysis, McGraw-Hill, New York, 2017.

MJMA15 (Unit II: Metric Spaces)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Analysis VI	MJMA15 (Metric Spaces)	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- study the topological properties of a metric space.
- help the students to read and to learn further topics in analysis
- motivate the students to make easier at understanding the use of functional analysis in applied problems.

Learning Outcomes:

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

- understand the distance function over the Euclidean spaces, space of all real valued continuous functions, sequence spaces etc.
- learn the geometrical meaning of each of the metric properties.
- classify the notion of open and closed balls for a given metric space.
- learn the convergence of a sequence, the Cauchyness of a sequence in a given metric space.
- get a clear concept of continuity of functions.

Syllabus:

Metric Spaces: Definition, Example of Metric Spaces. Convergence of a sequence, Spherical Neighbourhood, Closure of a Set, Closed Sets, Open Sets, Interior and Boundary Points.

Complete Metric Spaces: Cauchy sequences, Example of complete metric spaces, Example of incomplete metric Spaces.
Diameter of a set, Bounded Set, Cantor's Intersection Theorem, Baire's category theorem, Isometry, Completion of metric spaces.
Continuous mappings and related results.

Fixed Point Theorems: Contraction mapping, Idea of fixed point, Banach's contraction principle theorem and its simple applications.

Compact metric spaces, Uniform continuity, Total boundedness, sup and inf on compact sets. Sequential compactness.

Books Recommended:

1. B. K. Lahiri, *Metric Spaces*, The World Press Private Limited.
2. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill, 2017.
3. P. K. Jain and Khalil Ahmad, *Metric Spaces*, Narosa Publishing House, 2004.
4. M. N. Mukherjee, Elements of *Metric Spaces*, Academic Publishers, 2006.

MJMA16: Numerical Analysis

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major Course	Numerical Analysis	MJMA16	4	20	80	100	3	1	0

Learning Objectives:

The primary objectives of this course are to:

> Provide a theoretical understanding of various numerical methods/techniques which will be helpful in solving several mathematical problems occurred in real world situation. The theoretical knowledge should include an understanding of both the original problem being solved and of the numerical methods for its solution, including their derivation, error analysis, the applicability and limits of their appropriate use.

Learning Outcomes:

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

- Understand the potential pitfalls of numerical computations.
- Approximate a function and construct a polynomial for a given set of data using appropriate interpolation formula.
- Evaluate derivative at a value using an appropriate numerical method.
- Evaluate integrals using numerical integration formulae.
- Solve algebraic and transcendental equation using a suitable numerical method.
- Solve a large system of linear equations using an appropriate numerical method.
- Obtain numerical solutions of initial value problems using single-step methods.
- Interpret the geometrical significance of various numerical methods wherever possible.

Syllabus:

Accuracy of Approximate Calculations: Approximate numbers, Floating point form of numbers, Normalized scientific form of numbers, Overflow and underflow. Binary machine numbers, Significant figures, Rounding off numbers, Absolute, Relative and Percentage errors, Loss of significance. General formula for errors and its applications, Propagation of round off errors in arithmetic operations. Inherent errors in numerical computations.

Interpolation: Weierstrass' approximation theorem (statement only), Polynomial interpolation, Existence and uniqueness of interpolating polynomial, Derivation of the error in interpolation, Finite differences: Forward and Backward, Difference operators (Forward and Backward), Shifting operator, Properties and Relations between these operators; Difference table, Error in the entry values noise level, Differences of a polynomial, Newton's forward and backward interpolation formulae, Lagrange's interpolation formula, Inverse interpolation, Divided difference and their properties. Generalized Newton's divided difference formula. Confluent divided difference.

Numerical Differentiation: Differentiation formulae based on Newton's forward, backward and Lagrange's interpolation formulae. Error in differentiation. Two-point and three-point formulae.

Numerical Integration: Newton-Cotes quadrature formula (without error), Degree of precision, Trapezoidal rule, Simpson's one-third rule, Weddle's rule, Composite rules, Derivation of the error for Trapezoidal and Simpson's 1/3 rd rules.

Numerical Solution of Nonlinear Equations: Tabulation method, Bisection method, Regula-Falsi method, Secant method, Fixed point iteration method, Newton-Raphson method, Geometrical significance and convergence of these methods.

Numerical Solution of a System of Linear Equations: Directs methods: Gaussian elimination, LU factorization, Gauss-Jordan elimination; Operation counts, Matrix factorization, Matrix inversion. Iterative methods: Norms of vector and matrices, Jacobi, Gauss-Seidel, SOR and their convergence.

Initial Value Problems: Solution of first order ordinary differential equations: Picard's method, Taylor's method, Euler's method and its modified form (concept of Predictor-Corrector method), Error estimate and its convergence, Runge-Kutta method of second and fourth orders and their significance. Consistency and stability of single-step methods.

Books Recommended:

1. M. K. Jain, S.R. K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, Wiley Eastern Limited, (1991)
2. D. Kincaid, W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, American Mathematical Society, Rhode Island (2002)
3. R. L. Burden, J. D. Faires, Numerical Analysis: Theory and Applications, Cengage Learning, New Delhi (2005)
4. P. Niyogi, Numerical Analysis and Algorithms, Tata McGraw-Hill Publishing Company Limited, (2003)
5. A. Gupta and S. C. Bose, Introduction to Numerical Analysis, Academic Publisher, (1989)
6. N. Dutta and R. N. Jana, Introductory Numerical Analysis, Shreedhar Prakashani, (2001)

SEMESTER VII

MJMA17, MJMA18, MJMA19 & MJAMA01

MJMA17 (Unit I: Introduction to Lebesgue Integration)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Introduction to Lebesgue Integration	MJMA17	2	10	40	50	2	0	0

Learning Objectives:

- Introduce students to measurable functions and integration theory.
- Provide understanding of different convergence concepts in measure theory.
- Distinguish between Riemann and Lebesgue integrals with examples.
- Equip students with powerful tools such as Fatou's Lemma and Dominated Convergence Theorem for advanced analysis.

Learning Outcomes:

- Define and analyze measurable functions and their properties.
- Understand and apply the concepts of convergence: almost everywhere, in measure, and almost uniform convergence.
- Compare and contrast Riemann and Lebesgue integrals with applications.
- Utilize major theorems such as Egoroff's, Lusin's, Fatou's Lemma, and the Dominated Convergence Theorem in analysis problems.

Syllabus:

Measurable functions and their properties, Equivalent functions.
Simple functions, Measurable functions as limit of simple functions.
Sequence of measurable functions.
Almost everywhere convergence, convergence in measure and almost uniform convergence.
Riesz theorem, Egoroff's theorem, Lusin's theorem, Frechet's theorem.
Lebesgue's criterion for Riemann integrability.
Lebesgue integral of bounded function and its properties.
Comparison of Riemann and Lebesgue integrals.
Passage to the limit under the sign of integration, Bounded convergence theorem.
Summable functions and their integrals.
Fatou's Lemma, Monotone convergence theorem, Dominated convergence theorem.

Books Recommended:

1. H. L. Royden and P. Fitzpatrick, Real Analysis, Prentice Hall, 2010.
2. P. R. Halmos, Measure Theory, Prentice Hall, 1978.

3. P. K. Jain & V. P. Gupta, Lebesgue Measure and Integration, Wiley Eastern Ltd., 1986.
4 Z. Vulikh, A Brief Course in the Theory of Functions of a Real Variable, Mir Publishers, 1976.
5 P. Natanson, Theory of Functions of a Real Variable, Vol. 1, Frederick Ungar Pub. Co., 2016.
6 K. Rana, An Introduction to Measure and Integration, Narosa Publishing House, 2007.
7. S.N.Mukhopadhyay & Subhasis Ray, Measure and Integration : an Introduction, Springer 2025.

MJMA17 (Unit II: Complex Analysis II)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Complex Analysis II	MJMA17	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- compute definite and contour integral of complex valued functions of complex variables.
- gain the basic concept of entire and meromorphic functions.
- motivate the students to make easier at understanding the use of complex analysis in applied problems.

Learning Outcomes:

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

- integrate a complex valued function having certain types of singularities.
- classify the notion of different types of singularities.
- gain the knowledge about Maximum modulus, Minimum modulus theorems and Cauchy residue theorem.
- solve many applied problems using complex analysis.

Syllabus:

Simply connected region and primitives of analytic functions, Morera's theorem. Maximum and Minimum modulus theorem, Schwarz's lemma, Taylor's theorem.

Zeros of an analytic functions, Uniqueness of analytic functions, Singularities and classification of singularities, Laurent's theorem, Limit points of zeros and poles, Riemann's theorem on removable singularity, Casorati-Weierstrass theorem.

Cauchy's residue theorem, Evaluation of integration by residues theorem, Argument principle, Rouche's theorem, Open mapping theorem.

Behavior of a function at the point at infinity, Conformal mapping, Riemann mapping theorem (Statement only), Introduction to analytic continuation, Riemann Surface.

Books Recommended:

1. W. Rudin, *Real and Complex Analysis*, McGraw Hill, 1987.

2. R. V. Churchill and J. W. Brown, *Complex variables and Applications*, McGraw Hill, 2013.
3. E. T. Copson, *Theory of functions of a complex variable, Oxford University Press, 1970.*
4. E. C. Titchmarsh, *The theory of functions*, Oxford University Press, 1976.
5. Shanti Narayan, *Theory of functions of a Complex variable*, S. Chand & Co., New Delhi, 2005.
6. John B. Conway, *Functions of one complex variable*, Springer Interanational, 1995.
7. J. K. Lu, S. G. Zhong & S. Q. Liu, *Introduction to the theory of Complex Functions*, World Scientific Publishing Company, 2002.

MJMA18 (Unit I: Linear operators in inner product spaces)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Linear operators on inner product spaces	MJMA18	4	10	40	50	2	0	0

Learning objectives:

The objectives of this course are to:

- Study roles of metric properties like norm and angle in an inner product space to characterize linear operators on an inner product space.
- Introduce and develop the notion of adjoint of a linear transformation.
- Characterize normal, self-adjoint, orthogonal and unitary linear operators.
- Study Hermitian matrices with a focus to positive definite and semi-definite matrices.
- Develop polar decomposition of positive semi-definite matrices.
- Study bilinear and quadratic forms. Application of these forms to classify conic sections.

Learning outcomes:

After successful completion of this course the students will be able to:

- Realize orthogonality from abstract viewpoints which will help to identify governing intrinsic feature of orthogonality.
- Find an orthogonal basis of a finite dimensional inner product space.
- Classify normal linear operators.
- Appreciate the orthogonal diagonalizability of every real symmetric matrix.
- Characterize definite and semidefinite matrices.
- Find polar decomposition of semidefinite matrices.
- Apply results on bilinear and quadratic forms.

Syllabus:

Inner product spaces and norms. Gram-Schmidt orthogonalisation process, Orthogonal and orthonormal basis. Orthogonal complements and projection onto a subspace. Linear operators on inner product spaces, adjoint of

a linear operator; matrix representation of the adjoint. Normal, self adjoint operators, unitary and orthogonal operators; and their matrices. Orthogonal projections, the spectral theorems and consequences.

Hermitian matrices, properties and characterizations of Hermitian matrices. Congruence and diagonalization. Positive definite and semi-definite matrices, properties and characterizations, Sylvester's criterion. The polar decomposition of positive semi-definite matrices.

Bilinear and quadratic forms, characterization and classification theorems. Definite and semidefinite real quadratic forms. Congruence and Sylvester's Law of Inertia. Classification of conic sections and surfaces.

Books recommended:

1. Sheldon Axler, Linear Algebra Done Right, 3rd Ed., Springer, 2014.
2. R. B. Bapat, Linear Algebra and Linear Models, 3rd Ed., Springer, 2012.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 5th Ed., Pearson, 2022.
4. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Pearson, 2015.
5. Jin Ho Kwak and Sungpyo Hong, Linear Algebra, 2nd Ed., Birkhauser, 2004.
6. Vivek Sahai and Vikas Bist, Linear Algebra, 2nd Ed., Narosa, 2013.
7. Helene Shapiro, Linear Algebra and Matrices, American Mathematical Society, 2015.
8. Gilbert Strang, Introduction to Linear Algebra, 6th Ed., Wellesley-Cambridge Press, 2023.
9. Fuzhen Zhang, Matrix Theory : Basic Results and Techniques, 2nd Ed., Springer, 2011.

MJMA18 (Unit II: Functional Analysis)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Functional Analysis	MJMA18	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand the concept of norm, idea of convergent sequence, Cauchy sequence, etc.
- Recognize many important properties in finite dimensional normed linear spaces.
- Introduce the notion of bounded linear operator in normed linear spaces, find out relationships between boundedness and continuity.
- Present the concept of operator norm and establish different mathematical expressions of operator norm.
- Introduce the concept of Dual space and study some properties.
- Familiarize the students with the four fundamental theorems (Hahn-Banach theorem, Uniform Boundedness theorem, Open mapping theorem and Closed Graph theorem).
- Understand the concept of inner product spaces, their properties, how they relate to norm.
- Introduce the concept of Hilbert space and present some examples.
- Recognize the key role of Parallelogram law, Bessel's Inequality and Riesz representation theorem.

Learning Outcomes:

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

- Gain knowledge about normed linear space, convergent sequence, Cauchy sequence etc.
- Learn various important properties of finite dimensional normed linear spaces.
- Relate the behavior of bounded linear operators in normed linear space and establish the relation between bounded and continuity.
- Develop the idea of operator norm and deduce different mathematical expressions of operator norms.
- Gain knowledge about Dual space.
- Understand the statement of four fundamental theorems (Hahn-Banach theorem, Uniform Boundedness theorem, Open mapping theorem and Closed Graph theorem) which play key role in functional analysis.
- Learn to give examples of inner product spaces and can study various properties.
- Gain knowledge about Hilbert spaces and their properties.
- Know the utility of Parallelogram law, Bessel's Inequality and Riesz representation theorem in Hilbert spaces.

Syllabus:

Normed Linear Space: Definition, Convergent sequence, Cauchy sequence, Continuity of norm function, Definition of Banach space, Examples of Banach spaces, Properties of finite dimensional Banach spaces, Equivalent norms, Riesz lemma.

Linear operators on normed linear spaces: Boundedness and Continuity of linear operators, Norm of a bounded linear operator and its formulae, Bounded linear functional, Dual space.

Four fundamental theorems (Statement only): Hahn-Banach theorem, Open mapping theorem, Closed graph theorem, Uniform boundedness principle theorem.

Inner product space: Definition, Cauchy-Schwartz inequality, Continuity of inner product function, Parallelogram law, Relation between inner product space and normed linear space. Definition of Hilbert space and some examples, Orthogonal and orthonormal set and their simple properties, Bessel's inequality, Riesz representation theorem.

Books Recommended:

1. E. Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley & Sons, 1989.
2. G. Bachman & L. Narici, *Functional Analysis*, Academic Press, 2003.
3. C. Gottman & G. Pedrick, *First Course in Functional Analysis*, Prentice Hall of India, 2002.
4. A. H. Siddiqui, *Functional Analysis with Applications*, Tata-McGraw Hill, 1986.
5. G. F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill, 1963.
6. B. K. Lahiri, *Elements of Functional Analysis*, The World Press, 1982.
7. V. K. Krishnan, *Text Book of Functional Analysis*, Prentice Hall, 2004.
8. B. V. Limaye, *Functional Analysis*, Wiley Eastern, 2004.

MJMA19 (Unit I: Advanced Ordinary Differential Equations)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Advanced Ordinary Differential Equations	MJMA19	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand Existence and uniqueness theorems for ODEs.
- Recognize Sturm-Liouville systems.
- Understand method of solving systems of linear ordinary differential equations.
- Comprehend Adjoint and self-adjoint linear differential equations.

Learning Outcomes:

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

- Solve problems related to Existence and uniqueness theorems for ODEs.
- Solve problems related to Sturm-Liouville problems.
- Explain problems related to systems of linear ordinary differential equations.
- Solve problems related to self-adjoint linear differential equations.

Syllabus:

Existence and uniqueness**:** Continuity theorem, strong continuity theorem, existence and uniqueness theorem for 1st order and higher order differential equations, existence and uniqueness theorems for systems of differential equations.

Adjoint and self-adjoint linear differential equations: Abel's identity, oscillatory solutions. Nonoscillating solutions, estimation of distance between two successive zeros of solutions. Separation and comparison theorems.

Sturm-Liouville problems: Solution of Sturm-Liouville problems, Characteristic values and characteristic functions, Orthogonality of characteristic functions, expansion of a function in a series of orthogonal functions.

Green's function: Solutions of second order linear differential equations by Green's function approach for initial and boundary value problems.

Fundamental matrix. Exponential matrix function and their properties. Method of solving systems of linear ordinary differential equations by fundamental matrix and exponential matrix function.

Books Recommended:

1. Differential Equations, S. L. Ross, John Wiley and Sons, 2007.
2. Elementary Differential Equations and Boundary value problems, Boyce and DiPrima, Wiley, 2008.
3. A First Course in Ordinary Differential Equations, R. E. Langer, Wiley, 1954.
4. Differential Equations with Boundary-Value Problems, Zill and Wright, CENGAZE, 2017.
5. Ordinary Differential Equations, Ince, Dover, 2003.
6. Differential Equations, H. T. H. Piaggio, G. Bell and Sons, 1921.
7. Nonlinear Ordinary Differential Equations, Jordon and Smith, Cambridge, 2007.
8. Differential Inequalities, J. Szarski, PWN,1965.

MJMA19 (Unit II: Advanced Partial Differential Equations)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Advanced Partial Differential Equations	MJMA19	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Initiate a comparative discussion among well-posed and ill-posed partial differential equations from real-world examples.
- Develop analytical skills for solving some basic types of partial differential equations.
- Categorize second order partial differential equations and simplify their solution methods by reducing them to canonical forms.
- Explore the theory and applications of higher-order classical partial differential equations depending on initial and boundary value conditions.
- Focus on the application of knowledge and skills as partial differential equations are increasingly important in machine learning (ML), artificial intelligence (AI), and networking, offering a powerful framework for modeling complex phenomena and enhancing algorithm design.

Learning Outcomes:

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

- Classify higher-order partial differential equations and concerned canonical type of solutions.
- Understand the origin of diffusion, Laplace, wave equations and concerned analytical solution with modelling perspectives.
- To capture knowledge related to solving second order partial differential equations by choosing the most suitable method.
- Interpret the geometrical and physical significance of solutions, enlighten various real-world phenomena.

Syllabus:

Second order PDEs, The Cauchy-Kowalewskaya theorem. Idea of initial and boundary value problems. Non-homogeneous PDEs.

Classification of second order PDE. Elliptic, Hyperbolic and Parabolic PDEs. The Canonical forms for Hyperbolic, Parabolic and Elliptic equations.

Laplace equation: Harmonic function. Basic properties of harmonic functions, Laplace PDE. Boundary value problems, Uniqueness of solutions of Dirichlet and Neumann problems. Mean value theorem for harmonic functions. Maximum and minimum principles for harmonic functions. Uniqueness and stability of various BVPs.

Methods of solving PDEs: Separation of variables, Representation of solutions.

Boundary value problems of Dirichlet and Neumann: Dirichlet's principle, Dirichlet problem for a rectangle, The Neumann problem for a rectangle, Interior Dirichlet problem for a circle, Exterior Dirichlet problem for a circle, Interior Neumann problem for a circle, Green's function solution of Dirichlet's and Neumann's problem for sphere, formulation of Dirichlet's problems as a problem of integral equation, Poisson's integral solution.

Books Recommended:

1. Partial Differential Equations: An Introduction, W.A. Strauss, John Wiley & Sons Ltd., 2007.
2. An Elementary Course in Partial Differential Equations, T. Amarnath, Narosa, 2003.
3. Partial Differential Equations, F. Prasad and R. Ravindran, New Age International Publishers, 2022.
4. Elements of Partial Differential Equations, I. N. Sneddon, Tata McGraw-Hill, 2006.
5. Lawrence C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, Vol. 19, American Mathematical Society, 1998.
6. Kenneth S. Miller, Partial Differential Equations, Krieger Publishing Company, 2020.
7. F. John, Partial Differential Equations, Springer, 1981.
8. P. Prasad, R. Ravindran, Partial Differential Equations, John Wiley and Sons Ltd., 1985.
9. J. David Logan, Applied Partial Differential Equations, Springer, 2014.
10. E. DiBenedetto, Partial Differential Equations, Birkhäuser, 2009.
11. Linear Partial Differential Equations for Scientists and Engineers, Tyn Myint-U, L. Debnath Birkhäuser, 2017.
12. Nonlinear Partial Differential Equations for Scientists and Engineers, L. Debnath, Birkhäuser, 2012.

MJAMA01 (Unit I: Statics)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Statics	MJAMA01	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Analyse forces and their effects on objects at rest.

- Understand the concept of static equilibrium.
- Calculate reactions at supports, which are essential for understanding how structures are held in place.

Learning Outcomes:

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

- Analyse the properties of a force and a system of forces in 2D and 3D.
- Solve the equilibrium problems in various types of structures using analytical models.
- Understand resolution of forces which is fundamental to Continuum Mechanics.

Syllabus:

Coplanar forces: Conditions of equilibrium; Astatic equilibrium and Astatic centre.

Principle of virtual work for a single particle and rigid body, Examples.

Forces in three dimensions: Moment of a force about a line; Axis of a couple; Resultant of any couples acting on a body; Conditions of equilibrium of a system of forces acting on a body; Poinsot's central axis; Wrench, Pitch, Intensity and Screw.

Books Recommended:

1. S. L.Loney-An Elementary Treatise on Statics, Radha Publishing House, Kolkata,2003.
2. M.C.Ghosh-Analytical Statics, Sreedhar Prakashani, Kolkata,2004
3. A. S. Ramsey, Dynamics (Vols. I & II), Cambridge University Press,2009
4. H.Lamb-Statics and Hydrostatics.
5. M. Spiegel, Theory and Problems of Theoretical Mechanics, Schaum's Outline Series,2021.
6. E. J. Routh, A Treatise on Analytical Statics with Numerous Examples, Cambridge Library Collection, 2013.

MJAMA01 (Unit II: Hydrostatics)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major Course	Hydrostatics	MJAMA01	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce fundamental concepts and classify fluids based on their behavior and properties.
- Understand the concept of pressure in fluids at rest, the factors affecting it, and how to calculate it for various scenarios.
- Introduce the principles of fluid statics and applying them to analyze forces and pressure within fluids at rest.
- Understand the concept of center of pressure focus on both theoretical knowledge and practical application.

Learning Outcomes

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

- Identify different types of fluids and classify them based on their properties.
- Solve problems involving pressure in fluids at rest under the action of gravity only.
- Solve problems involving fluids in equilibrium under the action of external forces.
- Calculate the center of pressure for simple geometries (e.g., rectangular, circular) in both horizontal and inclined planes.

Syllabus:

Definition of fluid, Classification of fluids, Notion of stress.

Pressure at a point in a fluid. Pressure of heavy fluids in equilibrium under gravity.

Equilibrium of fluids in a given field of force: Pressure gradient; Surface of equipressure; Condition of equilibrium for a system of given forces.

Thrust on plane surfaces.

Centre of pressure; Depth of centre of pressure of a plane area under gravity; Effect of additional depth without rotation.

Books Recommended:

1. J. M. Kar, Hydrostatics, K. P. Basu Publishing Co., 2016
2. Md. M. Rahaman, Hydrostatics, New Central Book Agency Ltd., Kolkata, 2012.
3. B. Bhattacharyya, Hydrostatics, New Central Book Agency Ltd., Kolkata, 2013.
4. A. Mukherjee and N. K. Bej, Advanced Hydrostatics, Shreetara Prakashani, 2012.

Semester VIII

MJMA20, MJMA21 & MJAMA02, MJAMA03

MJMA20 (Unit I: Advanced Group Theory)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Advanced Group Theory	MJMA20	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- State and prove the structure theorem of finite abelian groups.
- Introduce the notion of group actions and prove the three theorems of Sylow with the help of it.
- Discuss the ideas of solvable groups.

Learning Outcomes:

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

- Identify groups of a given order up to isomorphism using Sylow's theorems.
- Prepare themselves to learn the main theorem of Galois theory which is a crowning achievement in algebra.

Syllabus:

Product of groups: Internal direct product of normal subgroups, necessary and sufficient conditions. Equivalence of internal and external direct products.

Structure of groups: Structure of finite abelian groups. The primary decomposition theorem and the fundamental theorem of finite abelian groups. Invariant factors and elementary divisors. Conjugation and the conjugacy class equation. Cauchy's Theorem for finite groups. The converse of the Lagrange's theorem for finite abelian groups. Center of a p-group is nontrivial.

Group action and Sylow's theorems: Group action, orbits and isotropy group. The class equation of a finite group. Burnside counting principle. Sylow's Theorems on finite groups. Applications of Sylow's theorems to test the simplicity of finite groups. If $1 \leqslant n < 60$ and n is not prime then no groups of order n is simple. Any simple group of order 60 is isomorphic to A5.

Solvability of groups: Solvable groups. Subgroups and homomorphic images of solvable groups. Commutator subgroups. Solvability of the symmetric groups Sn.

Books recommended:

1. Michael Artin, Algebra, 2nd Ed., Pearson, 2011.
2. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., Wiley, 2011.

3. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2013.
4. Joseph A. Gallian, Contemporary Abstract Algebra, 9th Ed., Cengage, 2020.
5. I. N. Herstein, Topics in Algebra, 2nd Ed., Wiley, 2006.
6. Charles C. Pinter, A Book of Abstract Algebra, 2nd Ed., Dover, 2010.
7. Vivek Sahai and Vikas Bist, Algebra, 4th Ed., Alpha Science, 2018.
8. M. K. Sen, Shamik Ghosh, Parthasarathi Mukhopadhyay and Sunil Kumar Maity, Topics in Abstract Algbera, 4th Ed., Universities Press, 2022.

MJMA20 (Unit II: Classical Mechanics)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Classical Mechanics	MJMA20	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand basic postulates of classical mechanics.
- Understand D'Alembert's principle and Lagrange's equations.
- Understand Hamilton's principle and principle of least action.
- Understand canonical transformations and related problems.

Learning Outcomes:

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

- Solve problems related to Lagrange's equations.
- Solve problems related to principle of least action.
- Solve problems related to canonical transformations.
- Understand different formalism for classical mechanics.

Syllabus:

Basic Postulates, Generalized coordinates, Constraints, D'Alembert's principle, Lagrange's equations, Hamilton's canonical equations, Hamilton's principle and principle of least action. Theory of small oscillations.

Canonical transformations, Generating functions, Poisson's bracket, Jacobi's identity, Poisson's theorem, Jacobi-Poisson theorem.

Books Recommended:

1. H. Goldstein, Classical Mechanics, Narosa Publishing House, New Delhi, 1980.
2. F. Gantmacher, Lectures in Analytical Mechanics, MIR Publishers, Moscow, 1975.

3. J.L. Synge and B.A. Griffith, Principles of Mechanics, McGraw-Hill, New York, 1970.
4. N.C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw Hill Pub. Company Ltd., New Delhi, 1998.
5. N.H. Louis and Janet D. Finch, Analytical Mechanics, C.U.P., 1998.
6. E.T. Whittaker, A Treatise of Analytical Dynamics of Particle and Rigid Bodies, C.U.P. 1977.
7. S.W. McCusky, An Introduction to Advanced Dynamics, Addison-Wesley Publ. Co. Inc. Massachusetts, 1953.
8. A.S. Ramsey, Dynamics Part-II, C.U.P., 1972.
9. L. Elsgolts, Differential Equations and the Calculus of Variations, MIR Publishers. Moscow, 1973.
10. R.H. Dicke and J.P. Wittke, Introduction to Quantum Mechanics, Addison Wesley, 1960.
11. Rydnik, ABC of Quantum Mechanics, Peace Publisher, Moscow, 2023.
12. F. Chorlton, Textbook of Fluid Dynamics, CBS Publications, Delhi, 1985.
13. A.S. Ramsey, Newtonian Attractions, Cambridge, 2007.
14. O.D. Kellog, Foundations of Potential Theory, Dover, 1963.

MJMA21 (Unit I: Methods of Applied Mathematics)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major Course	Methods of Applied Mathematics	MJMA21	3	15	60	75	3	0	0

Learning Objectives:

The primary objectives of this course are to:

Integral Transforms:

- Understand the foundational concepts, existence criteria and properties of Laplace and Fourier transforms.
- Develop proficiency in finding transforms and inverse transforms.
- Apply Laplace and Fourier transforms to solve initial and boundary value problems in ordinary differential equations and partial differential equations.

Integral Equations:

- Understand the nature and classification of integral equations: Volterra, Fredholm, and singular types.
- Convert differential equations into integral equations and vice versa.
- Develop various methods to solve integral equations.
- Study Fredholm alternative theorem and Hilbert-Schmidt theorem.
- Determine the conditions ensuring existence and uniqueness.

Calculus of Variations:

- Understand the concept of functionals and variation, including problems with fixed and moving boundaries.
- Derive and apply Euler's equation and transversality conditions.
- Analyze sufficient conditions for extremum using Jacobi, Legendre, and Weierstrass criteria.
- Formulate and solve variational problems with subsidiary conditions.

Learning Outcomes:

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

Integral Transforms:

- Compute Laplace and Fourier transforms and their inverses of different functions.
- Apply properties to simplify and solve problems.
- Solve ordinary and partial differential equations using Laplace and Fourier transforms.

Integral Equations:

- Classify and formulate Volterra, Fredholm and singular integral equations.
- Convert differential equations into integral equations and integral equations into differential equations.
- Find the resolvent kernel.
- Solve integral equations using methods such as:

Series solutions, Successive approximations, Successive substitutions

- Adomian and modified Adomian decomposition
- Laplace transforms.
- Analyze and solve Fredholm integral equations with separable kernels.
- Understand and apply Fredholm alternative theorem.
- Understand and apply Hilbert-Schmidt theorem for symmetric kernels.

Calculus of Variations:

- Formulate variational problems and apply Euler's equation to determine extrema.
- Solve problems involving higher-order derivatives and functionals with multiple independent variables.
- Determine sufficient conditions for extrema using advanced theoretical criteria.
- Address isoperimetric and constrained optimization problems using variational techniques.

Syllabus:

Integral Transforms:

Laplace transform: Convergence, continuity requirements, exponential order, existence and uniqueness, properties of Laplace transform, Heaviside's unit step function, convolution theorem, complex inversion formula, inverse Laplace transform, properties of inverse Laplace transform, solutions of ordinary and partial differential equations using Laplace transforms.

Fourier transform: Derivation of Fourier transform from Fourier series, properties of Fourier transform, convolution theorem, inverse Fourier transform, properties of inverse Fourier transform, Parseval's identity, solutions of ordinary and partial differential equations using Fourier transforms.

Applications of Laplace and Fourier transforms.

Integral Equations:

Basic introduction, conversion of ordinary differential equations into integral equations, conversion of integral equations into ordinary differential equations.

Linear integral equations of Volterra type: solution of Volterra integral equations by successive substitutions, successive approximations, series solution, Adomian decomposition, modified Adomian decomposition and Laplace transform methods, resolvent kernel.

Linear integral equations of Fredholm type: Solution of Fredholm integral equations by successive substitutions, successive approximations, series solution, Adomian decomposition and modified Adomian

decomposition methods, resolvent kernel, Neumann series, solution of integral equations with separable kernels, Fredholm alternative theorem, Hilbert-Schmidt theorem of integral equations for symmetric kernels.

Singular integral equations: Solution of singular integral equations by Laplace transform method.

Existence and uniqueness of integral equations.

Applications of integral equations.

Calculus of Variations:

Variational problems with fixed boundaries: The concept of variation and its properties, Euler's equation, functionals dependent on higher order derivatives, functionals dependent on functions of several independent variables.

Variational problems with moving boundaries: Transversality conditions, orthogonality conditions, variational problem with a moving boundary for a functional dependent on two functions, one sided variations.

Sufficient conditions for extremum: Field of extremals, weak and strong extremum, Jacobi condition, Weierstrass function, Legendre condition.

Variational problems with subsidiary conditions: I soperimetric problems.

Applications.

Books Recommended:

1. F. G. Tricomi, Integral Equations (Inter - Science).

2. A. M. Wazwaz, Linear and Nonlinear Integral Equations (Springer).

3. R. P. Kanwal, Linear Integral Equations (Academic Press).

4. P. P. G. Dyke, An introduction to Laplace Transforms and Fourier Series (Springer).

5. M. G. Spiegel, Laplace Transforms (Schaum's Outlines series).

6. J. L. Schiff, The Laplace Transform (Springer).

7. S. L. Ross, Ordinary Differential Equations (Wiley).

8. R. L. Bracewell, The Fourier Transforms and Its Applications (McGraw-Hill).

9. I. M. Gelfand and S. V. Fomin, Calculus of Variations (Prentice Hall).

10. A. S. Gupta, Calculus of Variations with Applications (Prentice Hall).

11. R. Weinstock, Calculus of Variations (Dover Publications).

MJMA21 (Unit II: IKS III--Indian Astronomy)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	IKS III (Indian Astronomy)	MJMA21	1	5	20	25	1	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce students to ancient records of the observations of motions of celestial bodies
- Acquire basic ideas of planetary models, and examine their scientific and scholastic implications in the modern milieu.

Learning Outcomes:

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

- Acquire knowledge on the history and development of Indian astronomy.
- Be familiar with Indian calendar systems in different regions of the country, as well as the underlying mathematical models developed by Indian astronomers.

Syllabus:

Calendar and Panchanga: Elements of Indian calendar systems in different regions of India, Gregorian calendar, Hindu calendar, Islamic calendar, and Panchanga.

Motion of celestial bodies: Introduction; Equations of center for the Sun and Moon; Observations of the motions of Sun, Moon, Nakshatra, and Graha in the Vedic corpus.

Planetary model: Basic planetary model of Aryabhata and its revision by Nilakantha

Eclipse: Lunar and Solar Eclipses.

Books Recommended:

1. History of Hindu Mathematics: A Source Book, B. Datta and A. N. Singh, Asia Publishing House, 1962.
2. Indian astronomy: An introduction by S. Balachandra Rao, Universities Press (India) Ltd, Hyderabad, 2000.
3. Studies in Indian Mathematics and Astronomy: Selected Articles of Kripa Shankar Shukla, Kolachana et. al. (eds.), Culture and History of Mathematics 12, HBA, 2019.
4. Indian Astronomy: A source book (Based primarily on Sanskrit Texts), Compiled by B. V. Subbarayappa and K. V. Sarma, Nehru Center, Bombay, 1985.
5. History of Astronomy in India by S. N. Sen and K. S. Shukla, 2nd Edition, INSA, Delhi, 2001.

MJAMA02 (Unit I: Theory of Equations)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Theory of Equations	MJAMA02	1	5	20	25	1	0	0

Learning Objectives:

The objectives of this course are to:

- Discuss different applications of standard inequalities of real numbers.
- Develop method for solving cubic and biquadratic polynomial equations.

Learning Outcomes:

After successful completion of this course, students will be able to:

- Apply standard inequalities of real numbers.
- Characterize nature of roots of a polynomial equation.
- Locate real roots of a polynomial equation.
- Solve cubic and biquadratic polynomial equations.

Syllabus:

Inequalities, AM $\geqslant$ GM $\geqslant$ HM and the Cauchy-Schwarz inequality (statement only); their applications.

Real polynomials; nature of the zeros and their positions; Descarte's rule of sign. Relation between roots and coefficients, symmetric functions of roots of a polynomial equation. Cardan's and Ferrari's method to solve cubic and biquadratic equations.

Books recommended:

1. Barnard and Child, Higher Algebra, Arihant, 2016.
2. S. K. Mapa, Higher Algebra: Classical, 9th Ed., Levant, 2019.

MJAMA02 (Unit II: IKS IV--Algebra in Ancient India)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	IKS IV (Algebra in Ancient India)	MJAMA02	1	5	20	25	1	0	0

Learning Objectives:

The objective of this course is to:

- Give an introductory idea on the history of the development of number system and algebra in India.

Learning Outcomes:

After successful completion of this course, students will be able to:

- Have a concrete idea on Indian Knowledge System regarding Mathematics and its development. They will know about the prime contributors of number system in Ancient India, and on their contributions.

Syllabus:

Numbers, fractions; zero and infinity in ancient India. The development of the decimal place value system and its consequence in simplification of all arithmetical operations.

Development of Bijaganita and number theory. Operations with 0. Squares, cubes, square roots and cube roots. The Cakravala method of solution of Joydeva and Bhaskara. Bhaskara's example $X^2 - 61Y^2 = 1$. Bhaskara's solution of a bi-quadratic equation.

Books recommended:

1. G. G. Joseph, Indian Mathematics, World Scientific, 2022.
2. S. G. Dani and S. K. Jain, Mathematics in Ancient Jaina Literature, World Scientific, 2024.
3. C. S. Seshadri, Studies in the History of Indian mathematics, HBA, 2010.

MJAMA02 (UNIT III: Topology)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Topology	MJAMA02 (UNIT III)	2	10	40	50	2	0	0

Learning Objectives:

The objectives of this course are to:

- Introduce the foundational concepts of general topology.
- Develop understanding of topological structures and their algebraic properties.
- Explore continuity, compactness, and connectedness in topological spaces.
- Apply separation axioms and function properties to classify spaces.

Learning Outcomes:

After successful completion of this course, students will be able to:

- Define and analyze topological spaces, subspaces, and related constructions.
- Work with continuous, open, closed functions and homeomorphisms.
- Apply separation axioms (T_0, T_1, T_2, etc.) and describe regular, normal, and completely normal spaces.
- Characterize compact and connected spaces, particularly with respect to the real line and continuous mappings.

Syllabus:

Topological spaces; examples, union and intersection of topologies, Discrete and Indiscrete topologies.
Base for a topology, necessary and sufficient condition for a base, Sub-base.
Neighbourhood system at a point, limit point of a set, closed sets and their algebra.
Derived set, closure of a set, Interior, boundary of a set - their relations.
Kuratowski closure operator and resulting topology, subspace and relative topology.
First and second axiom spaces, Lindeloff Theorem.
Continuous functions, open functions, closed functions, homeomorphism.
Product of finite number of spaces, sum and quotient spaces.
Separation axioms: T_0, T_1, T_2, regular, completely regular, normal, and completely normal spaces.
Open cover, compact spaces, compact sets, finite intersection property (F.I.P).
Characterization of compact sets of reals with usual topology.
Continuous image of compact spaces.
Connected spaces, connected sets of reals with usual topology, union of connected sets.
Continuous image of connected spaces, Components.

Books Recommended:

1. J. R. Munkres, Topology, Prentice Hall Inc., 1999.
2. S. T. Hu, Introduction to General Topology, Holden-Day Inc., 1966.
3. K. D. Joshi, Introduction to General Topology, Wiley Eastern Ltd., 2004.
4. J. Dugundji, Topology, Prentice Hall, New Delhi, 1966.
5. G. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Education, 2017.
6. W. Thorn, Topological Structure, Holt, Rinehart & Winston of Canada Ltd., 1966.
7. W. J. Pervin, Foundations of General Topology, Academic Press, 2014.

MJAMA03 (Unit I: Linear Programming Problem)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major	Linear Programming Problem	MJAMA03	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Impart knowledge and understanding of fundamentals in optimization problems.
- Provide mathematical modelling with a rigorous framework to analyze diverse linear systems in real life situation.
- Develop techniques in solving various linear programming problems using different methods.
- Explore transportation and assignment problems to acquire knowledge in the management system.

Learning Outcomes:

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

- Formulate and classify general linear programming problem.
- Identify and explore analytical results with the characteristics of an optimal solution.
- Apply appropriate techniques to determine optimal solution and corresponding nature using the simplex method.
- Use methods to explain transportation and assignment problems with some fundamental solution techniques.

Syllabus:

Optimization-Definition, Techniques and Facts. Diverse optimal solutions structure with graphical method and nature of solutions.
Basic concepts: Basis, replacing a vector in a basis. Solution of a system of linear equations- Basic solution, Basic feasible solution. Convex set-Extreme points. Matrix formulation of LPP. Standard form of LPP. Relation among the optimal solution of a LPP, Basic feasible solution and extreme point of the convex set of all feasible solutions.

Fundamental theorem of LPP, Theory of simplex method, Reduction of a feasible solution to a BFS; improving a basic feasible solution; Optimality checking, Unboundedness; Existence of alternative optimal solution. Simplex algorithm and the simplex tableau, Slack, Surplus and Artificial variables-introduction and its subsequent removal, Inconsistency and redundancy.

Two-phase simplex method. Solving simultaneous equations or inequations.

Concept of duality: Its economic interpretation. Construction of dual. The relation between feasible solution of dual and primal problems. Fundamental properties of Dual Problems. Weak duality theorem, Strong duality theorem, Fundamental duality theorem. Computational aspects of simplex method and duality. Dual simplex method-The algorithm and difference between regular simplex method and dual simplex method.

Transportation problems: Mathematical formulation; finding an initial basic feasible solution; The transportation algorithm-checking for optimality, improving a BFS. Degeneracy in transportation problem. Resolution of degeneracy in the initial stage. Resolution of degeneracy during solution stage. Unbalanced transportation problems. Maximization in transportation problems.

Assignment problems: Mathematical formulation; Hungarian assignment method, Unbalanced assignment problem. Maximization in assignment problem. Travelling salesman problem.

Books Recommended:

1. Linear Programming and Game theory, Chakraborty & Ghosh; Moulik Library, Kolkata, 2021.
2. Operations Research: An introduction, Hamdy A. Taha, 10th Edition, Pearson, 2011.
3. Operations Research: Principles and Practice-Ravindran, Phillips, Solberg; Wiley India, 1987.
4. Operations Research-Richard Bronson, Govindasami Naadimuthu, Tata McGraw-Hill, 1997.
5. Principles of Operations Research, Harvey M. Wagner, PHI, 1980.

6. Operations Research: Theory and Applications, J.K.Sharma, Macmillian India Ltd., 2012.
7. An introduction to Linear Programmig, Mukhopadhyay, Maity & Mazumdar, Kalimata Pustakalaya, Kolkata, 2016.
8. Linear Programming-Methods and Applications, S. I. Gass, Tata McGraw-Hill, New York, 1985.

MJAMA03 (Unit II: Advanced Numerical Analysis)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Major Course	Advanced Numerical Analysis	MJAMA03	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand the concept of piecewise polynomials, constructing interpolating polynomials for data points, and assessing the smoothness of the resulting function.
- Develop proficiency in understanding how to represent complex functions with simpler ones.
- Grasp the core idea of Gaussian quadrature, which involves selecting integration points and weights to match a polynomial of a specific degree exactly.
- Familiar with numerical methods for approximating eigenvalues and eigenvectors and understand their limitations.
- Introduce various numerical methods for solving IVPs and BVPs.
- Understand fundamental concepts of finite difference methods for solving PDEs.

Learning Outcomes

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

- Apply piecewise interpolation techniques to model data, estimate values between known points.
- Choose suitable approximation methods and apply to solve practical problems in different domains, such as approximating value functions in reinforcement learning or fitting a curve to data points.
- Compute definite integrals with a higher degree of accuracy using Gaussian quadrature.
- Apply the learned concepts and techniques to solve problems involving eigenvalues and eigenvectors, such as finding the dominant eigenvalue and corresponding eigenvector of a matrix.
- Solve simple IVPs by multi-step methods and BVPs using the shooting method and finite difference methods.
- Use the finite difference method to solve real-world problems modeled by PDEs in their respective fields of study.

Syllabus:

Interpolation: Piecewise polynomial interpolation, Hermite interpolation formula, Error in Hermite interpolation. Cubic spline interpolation, Bivariate interpolation: Local matching methods, Global methods.

Approximation of Functions: Norms, Least-squares polynomial approximation, Orthogonal polynomials, Gram-Schmidt orthogonalization, Chebyshev polynomials, Uniform approximation in mini-max sense of error, Lanczos economization.

Numerical Integration: Errors in Newton-Cotes quadrature formula, Gauss-Legendre and Gauss-Chebyshev quadrature formulae, Romberg integration.

Matrix Eigenvalues and Eigenvectors: Power method, inverse power method and Deflation method for square matrices; Jacobi's method, Givens' method, Householder's method and The QR algorithm for symmetric matrices, Singular Value Decomposition.

Numerical Solution of Initial Value problems (IVP) and Boundary Value Problems (BVP) for ODE: First Order Equations: Multi-step Predictor-Corrector Methods: Adams-Bashforth method, Adams-Moulton method, Milne's method --- Convergence and stability. Two-Point Boundary Value problems for ODE: Shooting method, Finite difference method.

Numerical Solution of Partial Differential Equations (PDE) by Finite Difference Methods: Classification of second order PDE, Representation of derivatives by forward, backward and central differences, Thomas Algorithm, Parabolic Equation (Heat-Conduction Equation) (1D) by explicit finite difference and implicit Crank-Nicolson methods, consistency, stability and convergence, Lax equivalence theorem, Poisson Equation on a rectangular region, Hyperbolic Equation (Wave Equation) in one space dimension.

Books Recommended:

1. M. K. Jain, S. R. K. Iyengar, R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publisher, New Delhi (2007).
2. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons (1989).
3. A. Gupta and S. C. Bose, Introduction to Numerical Analysis, Academic Press (1989).
4. P. Niyogi, Numerical Analysis and Algorithms, Tata McGraw-Hill, New Delhi (2004).
5. E. Isaacson, H. B. Keller, Analysis of Numerical Methods, Dover Publications, Inc., New York (1966).
6. D. Kincaid, W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, American Mathematical Society, Rhode Island (2002).
7. R. L. Burden, J. D. Faires, Numerical Analysis: Theory and Applications, Cengage Learning, New Delhi (2005).
8. S. D. Conte and Carl de Boor, Elementary Numerical Analysis - An Algorithmic Approach, 3rd Edition, McGraw Hill (1980).
9. P. Niyogi, S. K. Chakrabartty, M. K. Laha, Introduction to Computational Fluid Dynamics, Pearson, 2005.
10. G. D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 3rd Edition, 1986
11. Joe D. Hoffman, Numerical methods for Engineers and Scientist, McGraw-Hill, 1993.

MINOR COURSES IN MATHEMATICS
[Discipline-Specific Minor Courses]

Semesters I & II

MNMA01: Differential Calculus & IKS V, Integral Calculus, and Vector Calculus

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Minor	Differential Calculus & IKS V (Calculus in Ancient India), Integral Calculus, and Vector Calculus	MNMA01	(1+1)+1+1=4	20	80	100	3	1	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce core ideas of differential, integral, and vector calculus together with historical insights from Indian mathematics.
- Develop competence in curve analysis, series expansions, and vector-field techniques.
- Apply calculus concepts to geometrical, physical, and astronomical models inspired by both Western and Indian traditions.
- Foster appreciation for India's contributions—especially the Kerala School—to modern analytical methods.

Learning Outcomes:

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

- Prove and apply mean-value theorems, power-series expansions, and multivariable differentiation results.
- Compute arc lengths, areas, volumes, surface areas and evaluate Beta and Gamma integrals and other improper integrals.
- Use gradient, divergence, curl and the classical integral theorems to analyse scalar and vector fields.
- Explain and employ Kerala-school infinite-series techniques for π, $\sin x$, $\cos x$ and related quantities, relating them to modern convergence theory.

Syllabus:

Unit I— Differential Calculus

Rolle's Theorem (statement), Lagrange's & Cauchy's Mean-Value Theorems
Taylor's & Maclaurin's Theorems (statements),Necessary conditions for existence of power series; Series expansions: e^x, sin x, cos x, log(1+x), $(1+x)^n$; Envelope, asymptotes & curvature.
Multivariable topics: Limits & continuity of functions of several variables, Partial derivatives & differentiability, Schwarz's and Young's Theorems (statements), Homogeneous functions & Euler's Theorem.

Unit II— IKS V (Calculus in Ancient India)

Derivative-like reasoning in Indian astronomy (rates of planetary motion);
Madhava's Rsine & Rcosine series and π-series approximations; Trigonometric tables & interpolation techniques in Kerala astronomy; Maxima & minima reasoning in temple layout & architectural design; Early Indian geometric depictions of curves.

Unit III—Integral Calculus

Reduction formulae for $\int \sin^n x\, dx$, $\int \cos^n x\, dx$, Parametrisation of curves & quadrature, Rectification, volumes & surfaces of revolution, Improper integrals; Beta & Gamma functions.

Unit IV—Vector Calculus

Vector functions: limits, continuity, differentiation, integration; Scalar & vector fields—gradient, divergence, and curl; Line, surface & volume integrals; Green's, Stokes' & Gauss' theorems (statements & applications).

Books Recommended:

Differential and Integral Calculus

10. Konrad Knopp, *Theory and application of Infinite series*, Dover Publication, 1990.
11. S. K. Mapa, *Introduction to Real Analysis*, Sarat Book Distributors, Revised 8th Edition, 2021.
12. R. R. Goldberg, *Methods of Real Analysis*, Oxford and IBH Publishing Co. Pvt. Ltd, 2021.
13. P. C. Bhakta, *A Course of Real analysis*, Sarat Book Distributors, 2014.
14. David. V. Widder, *Advanced Calculus*, Prentice Hall of India Private Limited.
15. S. C. Malik and Savita Arora, *Mathematical Analysis*, New Age International (P) Ltd. Publishers, 2005.
16. K. C. Maity and R. K. Ghosh, *An introduction to Analysis, Integral Calculus*, Books and Allied (P) Ltd, 2013.
17. S. N. Mukhopadhyay and S. Mitra – *Mathematical Analysis* – Vol-II (U. N. Dhar & Sons. Pvt. Ltd.), 2014.
18. S. Ponnusamy, *Foundations of Mathematical Analysis*, Birkhauser, 2011.

Vector Calculus

1. Vector Calculus, S. J. Colley. (Pearson)
2. Vector Calculus, J. E. Marsden and A. J. Tromba (Freeman, W. H. & Company)
3. Vector Analysis, M. R. Spiegel (Schaum's Outlines)
4. Vector and Tensor Analysis, U. Chatterjee and N. Chatterjee (Academic Publisher)
5. Vector Analysis, J.G. Chakravorty and P.R. Ghosh (U. N. Dhur & Sons)
6. Vector Analysis with Applications, A. A. Shaikh and S. K. Jana (Narosa Publishing House Pvt. Ltd., New Delhi)
7. A Text Book of Vector Analysis, Shanti Narayan (S. Chand Publishing)

IKS V (Calculus in Ancient India)

1. *Yuktibhāṣā* by Jyesthadeva — selected English/Malayalam translations
2. *Āryabhaṭīya* by Āryabhaṭa.

3. UGC Sourcebook: *Kerala School of Mathematics and Astronomy*.
4. S. R. Sarma, *Mathematics and Astronomy in India*.
5. P. P. Divakaran, *The Mathematics of India: Concepts and Connections*, Springer, 2018.

Semesters III & IV

MNMA02: (Unit I: Abstract Algebra; Unit II: Linear Algebra)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Minor	Abstract Algebra	MNMA02	2	10	40	50	2	0	0
	Linear Algebra	MNMA02	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Study real polynomials, their roots, and classical methods for solving low-degree equations.
- Introduce fundamental concepts of group and ring theory with examples.
- Develop methods for solving linear systems and understanding matrix rank and echelon forms.
- Explore vector spaces, subspaces, and concepts of basis and dimension in R^2 and R^3.
- Understand eigenvalues, eigenvectors, and diagonalization of matrices.

Learning Outcomes:

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

- Analyze roots of real polynomials and apply Descartes' rule, Cardan's and Ferrari's methods.
- Identify and verify groups, subgroups, and rings with standard examples.
- Solve systems of linear equations using row reduction and understand rank and solution structure.
- Determine linear independence, basis, and dimension of vector spaces and subspaces in R^n.
- Compute eigenvalues and eigenvectors, determine diagonalizability, and apply the Cayley-Hamilton theorem.

Syllabus:

Unit-I: Abstract Algebra

Real polynomials; nature of the zeros and their positions; Descarte's rule of sign. Relation between roots and coefficients, symmetric functions of roots of a polynomial equation. Cardan's and Ferrari's method to solve cubic and biquadratic equations.

Introduction to groups, definition and examples of groups including symmetries of a square, dihedral groups, permutation groups and matrix groups. Elementary properties of groups, order of an element in a group. Cyclic groups, definition and examples. Elementary properties. Definition and examples of subgroups, subgroup tests. Centralizer, normalizer, center of a group. Algebra of subgroups.

Definition and examples of rings, properties of rings, subrings. Integral domains and fields, characteristic of a ring.

Unit-II: Linear Algebra

Systems of linear equations, homogeneous and non-homogeneous systems. The matrix equation AX=b, row reduction and echelon forms, uniqueness of reduced echelon form. Pivot positions, basic and free variables, parametric description of the solution set. Rank of a matrix (in terms of non-zero rows in the unique reduced row echelon form); existence and uniqueness theorem for solutions of a system of linear equations.

Vector spaces, subspaces, algebra of subspaces, direct sum of subspaces. Linear combination of vectors, linear span. Linear independence. Basis and dimension, dimension of subspaces. Geometric classification of the subspaces of R^2 and R^3

Eigenvalues and eigenvectors of a matrix, Characteristic polynomial. Eigen spaces and diagonalizability of a matrix. The Cayley-Hamilton theorem for matrices(statement only) and it's applications.

Books recommended:

1. Barnard and Child, Higher Algebra, Arihant, 2016.
2. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 5th Ed., Pearson, 2022.
3. Joseph A. Gallian, Contemporary Abstract Algebra, 9th Ed., Cengage, 2020.
4. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Pearson, 2015.
5. David C. Lay, Steven R. Lay and Judi J. McDonald Linear Algebra and its Applications, 5th Ed., Pearson, 2023.
6. S. K. Mapa, Higher Algebra: Classical, 9th Ed., Levant, 2019.
7. S. K. Mapa, Higher Algebra: Abstract and Linear, 15th Ed., Levant, 2020.
8. Charles C. Pinter, A Book of Abstract Algebra, 2nd Ed., Dover, 2010.
9. M. K. Sen, Shamik Ghosh, Parthasarathi Mukhopadhyay and Sunil Kumar Maity, Topics in Abstract Algbera, 4th Ed., Universities Press, 2022.
10. Gilbert Strang, Linear Algebra and its Applications, 4th Ed., Cengage, 2005.

Semesters V & VI

MNMA03: Differential Equations and their Applications

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical

Minor Course	Differential Equations and their Applications	MNMA03	4	20	80	100	3	1	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce fundamental concepts and classifications of ordinary and partial differential equations, including their formation from physical and geometrical problems.
- Develop skills in solving first order linear and nonlinear ordinary and partial differential equations using different methods.
- Explore different solution techniques for higher order linear ordinary differential equations with both constant and variable coefficients.

Learning Outcomes

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

- Define and classify ordinary and partial differential equations by order, degree, linearity, and type.
- Form ODEs and PDEs from physical and geometric descriptions or real-world problems.
- Solve first-order ODEs using different methods such as separation of variables, integrating factors, and techniques for exact and homogeneous equations.
- Solve special types of higher-degree first-order ODEs, including Clairaut's equation and equations solvable for p, x, or y.
- Analyze and solve second-order and higher-order linear differential equations using symbolic operators, and variation of parameters.
- Solve linear systems of differential equations and homogeneous equations with variable coefficients such as Euler's equation.
- Solve first-order PDEs (linear and nonlinear) using Lagrange's and Charpit's methods.
- Model and solve real-world problems using ordinary and partial differential equations (ODEs and PDEs), demonstrating the ability to apply mathematical concepts in interdisciplinary contexts.

Syllabus:

Basic Concepts:
Definitions of ordinary differential equation (ODE), formation of ODEs by elimination of arbitrary constants, formation of ODEs from real-world problems, geometrical and physical interpretations of solutions, concept of linear and nonlinear ODEs, concept of initial value problems and boundary value problems in ODEs.

First Order ODEs of first Degree:
Existence and uniqueness theorem for 1st order and higher order differential equations (Statement only), general solution and particular solution of 1st order IVP, separable equations and equations reducible to this form, homogeneous equations, exact equations and condition for exactness, integrating factor and methods of finding integrating factors, linear equations, equations reducible to 1st order linear equations, orthogonal and oblique trajectories.

First Order ODE of Higher Degree:
Equations solvable for p, x, and y, Clairaut's equation, singular solution.

Higher Order Linear ODEs with Constant Coefficients:
Linearly dependent and independent solutions, Wronskian and its properties,

general solution of homogeneous equation of second order, principle of superposition for homogeneous equation, finding out particular integrals (P.I.) by symbolic operator D, solution of 2nd order ODEs by variation of parameters, linear simultaneous differential equations.

Homogeneous Linear ODEs with Variable Coefficients:
Euler's equation, exact higher order ODEs and some special forms.

Partial Differential Equations (PDEs):
Definitions, order and degree of partial differential equations, concept of linear and non-linear partial differential equations, formation of first order partial differential equations, linear partial differential equation of first order, Lagrange's method, Charpit's method.

Applications:
Applications of ordinary and partial differential equations to real-world problems in physics, biology, engineering and other applied fields.

Books Recommended:

1. P. R. Ghosh and J. G. Chakraborty, Differential Equations (U. N. Dhar & Sons).
2. E. D. Rainville, P. E. Bedient and R. E. Bedient, Elementary Differential Equations (Pearson).
3. D. G. Zill, A First Course in Differential Equations with Modeling Applications (Cengage).
4. S. L. Ross, Introduction to Ordinary Differential Equations (Wiley).
5. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems (Wiley).
6. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations (McGraw-Hill).
7. I. N. Sneddon, Elements of Partial Differential Equations (McGraw-Hill).
8. Tyn Myint-U and L. Debnath, Linear Partial Differential Equations for Scientists and Engineers (Birkhauser).
9. L. Debnath, Nonlinear Partial Differential Equations for Scientists and Engineers (Birkhauser).

Semesters VII & VIII

MNMA04: (Unit I: Linear Programming Problem)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Minor	Linear Programming Problem	MNMA04	2	10	40	50	2	0	0

Learning Objectives

The primary objectives of this course are to:

- Introduce convex sets, extreme points, and feasible solutions.
- Develop the simplex method and its extensions.
- Explain duality and primal-dual relationships.

- Solve transportation and assignment problems.

Learning Outcomes

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

- Identify basic feasible solutions and extreme points.
- Solve LPPs using simplex, two-phase, and Big-M methods.
- Formulate and interpret dual problems.
- Apply methods to solve transportation and assignment problems efficiently.

Syllabus:

Convex and polyhedral sets, Hyperplanes, Extreme points; Basic solutions, Basic feasible solutions, Correspondence between basic feasible solutions and extreme points.

Simplex method: Optimal solution, Termination criteria for optimal solution of the linear programming problem, Unique and alternate optimal solutions, Unboundedness; Simplex algorithm and its tableau format; Artificial variables, Two-phase method, Big-M method.

Duality Theory: Motivation and formulation of dual problem, Primal-Dual relationships, Fundamental theorem of duality; Complementary slackness.

Transportation Problem: Definition and formulation, Northwest-corner, Least-cost, and Vogel's approximation methods of finding initial basic feasible solutions; The Transportation Algorithm-checking for optimality, improving a B.F.S. Degeneracy in Transportation Problem. Resolution of degeneracy in the initial stage. Resolution of degeneracy during the solution stage. Unbalanced Transportation Problems. Assignment Problem: Mathematical formulation and the Hungarian method of solving.

Books Recommended:

1. Bazaraa, Mokhtar S., Jarvis, John J., & Sherali, Hanif D. (2010). Linear Programming and Network Flows (4th ed.). John Wiley and Sons. Indian Reprint
2. Hillier, Frederick S. & Lieberman, Gerald J. (2021). Introduction to Operations Research (11th ed.). McGraw-Hill Education (India) Pvt. Ltd.
3. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson
4. Thie, Paul R., & Keough, G. E. (2008). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd. Indian Reprint 2014.

MNMA04 (Unit II: Numerical Methods)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Minor Course	Numerical Methods	MNMA04	2	10	40	50	2	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand the importance of error analysis and their propagation.
- Understand techniques of interpolation.
- Understand methods for numerically solving definite integrals.
- Introduce the basic concepts of solving algebraic, transcendental equations and large system of linear equations.

Learning Outcomes

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

- Calculate errors induced in the values by truncation of a series expansion.
- Fit polynomials to a given set of data points.
- Evaluate definite integrals using suitable numerical techniques.
- Find roots of non-linear equations and solutions of large system of linear equations.

Syllabus:

Approximate numbers. Significant figures, Rounding off numbers. Errors –Absolute, Relative and percentage errors. The general formula for errors and its applications.

Finite differences, Difference table, propagation of error in a difference table. Differences of a polynomial. Polynomial interpolation. Error in polynomial interpolation. Newton's forward and backward interpolation formulae. Lagrange's interpolation formula.

Numerical integration: Trapezoidal rule, Simpson's one-third rules. Composite rules. Geometrical significance. (No derivation of error term)

Numerical solution of algebraic and transcendental equations. Bisection method, Method of fixed point iteration, Newton Raphson's method. Geometrical significance and convergence.

Numerical solution of a system of linear equations: Iterative methods: Gauss Jacobi and Gauss Seidel.

Books Recommended:

1. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, Wiley Eastern Limited, (1991).
2. P. Niyogi, Numerical Analysis and Algorithms, Tata McGraw-Hill Publishing Company Limited, (2003).
3. A. Gupta and S. C. Bose, Introduction to Numerical Analysis, Academic Publisher, (1989).
4. N. Dutta and R. N. Jana, Introductory Numerical Analysis, Shreedhar Prakashani, (2001).
5. J. B. Scarborough, Numerical Mathematical Analysis, Oxford and IBM Pub. Co., (1966).

SKILL ENHANCEMENT COURSES IN MATHEMATICS

Semester I
SEC01A & SEC01B

SEC01A: (Unit I: Programming in C-Theory)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Skill Enhancement Course	Programming in C-Theory	SEC01A	1	5	20	25	1	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce students to the fundamental concepts of computer programming languages.
- Develop a clear understanding of the concepts of algorithms and flowcharts as tools for problem-solving and program planning.
- Enable students to understand and use constants, variables, data types, and expressions in C programs effectively.
- Provide knowledge on the use of arithmetic, relational, and logical operators for performing operations and building conditions in C.
- Train students to implement decision-making and branching mechanisms such as `if', `if-else', `nested if', and `switch' statements to control the flow of execution.
- Introduce control structures like `while`, `do-while`, and `for` loops for iterative programming.
- Teach students to declare, initialize, and manipulate one-dimensional, two-dimensional, and multi-dimensional arrays in C.
- Encourage modular programming by using user-defined functions, including concepts like variable scope, function arguments, return types, recursion, and array passing.
- Provide a solid foundation in pointer concepts and their applications in function calls and array manipulation.
- Introduce file handling in C, including file operations like opening, reading, writing, and processing files for data storage and retrieval.

Learning Outcomes:

After successful completion of this course, students will be able to:

- Explain the structure and purpose of programming languages
- Draw and interpret algorithms and flowcharts to solve simple computational problems.
- Write and debug basic C programs using appropriate syntax for data types, variables, and expressions.
- Develop programs using decision-making and branching constructs for real-world logical scenarios.

- Apply loop structures (while, do-while, for) to perform iterative tasks efficiently.
- Design and use arrays for structured data storage and retrieval, including multi-dimensional arrays.
- Manipulate pointers for direct memory access, and handle arrays and functions with pointer-based operations.
- Implement file handling techniques for data persistence, including reading from and writing to files in C.

Syllabus:

Computer Language: Algorithm, flowchart, concept of programming languages, machine language, assembly language, low and high-level languages, interpreter, compiler, assembler, source and object programs, importance of C programming.

Constants, Variables, and Data type of C-Program: Character set, constants and variables data types, expression, assignment statements, declaration.

Operation and Expressions: Arithmetic operators, relational operators, logical operators.

Decision Making and Branching: Decision making with if statement, if-else statement, nesting if statement, switch statement, break and continue statements.

Control Statements: While statement, do-while statement, for statement.

Arrays: One-, two-, and multi-dimensional arrays, declaration of arrays, initialization of one and multi-dimensional arrays.

User-defined Functions: Definition of functions, scope of variables, return values and their types, function declaration, function call by value, nesting of functions, passing of arrays to functions, recursion of functions.

Pointers: Pointer declarations, passing pointers to a function, pointers and one dimensional and multidimensional array, arrays of pointers.

File Handling: Opening and closing of data files, reading, writing and processing data files.

Books Recommended:

1. B. Gottfried and J. Chhabra, Programming With C (Tata Mcgraw Hill).
2. B. W. Kernighan and D. M. Ritchi, The C-Programming Language (Prentice Hall).
3. E. Balagurnsamy, Programming in ANSI C (Tata McGraw Hill).
4. Y. Kanetkar, Let Us C (BPB Publication).
5. C. Xavier, C-Language and Numerical Methods (New Age International).
6. B. W. Kernighan and D. M. Ritchi, The C-Programming Language (Prentice Hall).

SEC01B: (Unit II: Programming in C-Laboratory)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Skill Enhancement Course	Programming in C-Laboratory	SEC01B	2	10	40	50	0	0	2

Learning Objectives:

The primary objectives of this course are to:

- Introduce the fundamentals of C programming.
- Develop logical thinking using programming constructs.
- Enable students to write and debug C programs.
- Solve problems with the help of C programming.

Learning Outcomes:

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

- Understand the syntax and semantics of C.
- Apply programming constructs such as loops, functions, and conditionals.
- Implement file operations.
- Solve different problems by writing programs in C.

Syllabus:

PART-A:
Basic C program: Writing basic C programs, executing and debugging a C program, managing input and output operations.

Operators and Expressions: writing C programs with arithmetic operators, relational operators, logical operators, and assignment operators.

Decision Making and Branching: writing decision making C programs using control statements like if, if...else, if...else ladder, nested if, and switch cases.

Looping: writing C programs using do, while, do-while, and for loops.

Arrays: writing C programs using one- and two-dimensional arrays with special emphasis on matrices.

Functions: writing C programs using user-defined functions, function calls, function declaration, no arguments and no return values, arguments but no return values, arguments with return values, no arguments but returns a value, passing arrays to functions.

Pointers and Structures: writing C programs with pointers and structures.

File Management: writing C programs using files for reading input and storing output.

Dynamic Memory Allocation: writing C programs using malloc and calloc functions.

PART-B:

Solutions of different mathematical problems by integrating the above concepts.

Books Recommended:

1. Gottfried and J. Chhabra, Programming With C (Tata McGraw Hill).
2. B. W. Kernighan and D. M. Ritchi, The C-Programming Language (Prentice Hall).
3. Balagurnsamy, Programming in ANSI C (Tata McGraw Hill).
4. Y. Kanetkar, Let Us C (BPB Publication).
5. C. Xavier, C-Language and Numerical Methods (New Age International).

Semester II
SEC02A & SEC02B

SEC02A: (Unit I: Artificial Intelligence & Machine Learning)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Skill Enhancement Course	Artificial Intelligence & Machine Learning	SEC02 A	1	5	20	25	1	0	0

Learning Objectives:

The primary objectives of this course are to:

- Build a foundational understanding of artificial intelligence (AI) and machine learning (ML).
- Introduce key terminology, tools, and real-world applications.
- Inspire further exploration in intelligent systems and data-driven technologies.

Learning Outcomes:

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

- Understand core concepts and objectives of AI and ML.
- Distinguish between AI, ML, and deep learning.
- Identify major ML algorithms and their applications.
- Recognize the societal impact and ethical considerations of AI.
- Gain basic hands-on experience with simple AI/ML tasks using Python.

Syllabus:

Introduction to Artificial Intelligence (AI): What is AI? History and evolution, types of AI: narrow AI, general AI, super AI, applications of AI in healthcare, finance, robotics, education, etc., ethical issues and the role of AI in society.

Fundamentals of Machine Learning (ML): Definition of ML and its relationship with AI, Types of ML: supervised, unsupervised, reinforcement learning. Key algorithms: Linear Regression, k-NN, decision trees, dimensionality reduction, clustering.

Concepts in ML: Data representation and basic preprocessing, model training vs testing. Evaluation metrics: accuracy, confusion matrix.

Real-World Applications: Recommendation systems, image recognition, voice assistants and chatbots.

Practical Tools: Introduction to free tools and platforms, simple hands-on exercises using Python.

Books Recommended:

1. M. A. Boden, AI: A Very Short Introduction (Oxford University Press).
2. E. Rich, K. Knight and S. B. Nair, Artificial Intelligence (McGraw Hill).
3. T. M. Mitchell, Machine Learning (McGraw Hill).
4. A. C. Müller and S. Guido, Introduction to Machine Learning with Python (O'Reilly).

SEC02B: (Unit II: Python Programming)

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Skill Enhancement Course	Python Programming	SEC02B	2	10	40	50	0	0	2

Learning Objectives

This course aims to:

- Introduce the fundamentals of Python programming.
- Foster logical thinking through code.
- Enable students to write, test, and debug Python programs.
- Apply Python libraries and tools to solve practical problems.

Learning Outcomes

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

- Understand Python syntax, semantics, and programming paradigms.
- Use control structures, functions, and recursion effectively.
- Work with built-in data structures like strings, lists, tuples, sets, and dictionaries.
- Perform file operations and implement exception handling.
- Develop modular programs using standard and user-defined libraries.
- Solve different mathematical problems using Python programming.

Syllabus:

PART A:

Introduction to Python: History and Python overview, Python identifiers, reserved keywords, variables, standard data types, operators, statement and expression, string operations, Boolean expressions, control statements, iteration.

Functions: Built-in functions, composition of functions, user defined functions, parameters and arguments, function calls, Python recursive function, anonymous functions.

Data Structures: Strings and built-in string functions. Lists: operations and methods tuples, sets. Dictionaries: creation and manipulation.

Files and Exceptions: Text files, directories, exceptions, exception with arguments, user-defined exception.

Classes and Objects: Class definition, creating objects, objects as arguments, objects as return values, built-in class attributes, inheritance, method overriding, data encapsulation.

Problem-Solving with Python: Writing and debugging Python programs, solving problems using structured and modular approaches, problem using list comprehension.

PART-B:

Solutions of different mathematical problems by integrating the above concepts.

Books Recommended:

1. M. C. Brown, Python: The Complete Reference (McGraw Hill)
2. E. Balagurusamy, Introduction to computing and problem solving using Python (McGraw Hill)
3. L. Ramalho, Fluent Python: Clear, Concise, and Effective Programming (O'Reilly)

Semester III
SEC03

SEC03: Number Theory and Cryptography

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
SEC	Number Theory and Cryptography	SEC03	3	15	60	75	3	0	0

Learning Objectives:

The primary objectives of this course are to:

- Introduce the fundamental concepts of elementary number theory.
- Introduce the notion of congruence and develop machinery to solve divisibility problems using that.
- State and prove fundamental theorems involving arithmetic functions.
- Introduce quadratic residues and to state the law of quadratic reciprocity.
- Introduce the basics of cryptography.

Learning Outcomes:

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

- Solve elementary number theory problems by using the techniques learnt in this course.
- See the connection between abstract algebra and number theory more clearly.
- Use the law of quadratic reciprocity to answer various questions related to remainders.
- Familiarize with the fundamentals of cryptography.

Syllabus:

Basic Concepts: Review of elementary number theory, divisibility of integers, fundamental theorem of arithmetic, infinitude of prime numbers.

Congruence: Congruence, definition of congruence as an equivalence relation on integers, Illustration of finding remainder of an integer upon division by another integer, linear congruence, Chinese remainder theorem for Z and its applications.

Arithmetic functions: Definition of arithmetic functions, multiplicative and completely multiplicative functions, Möbius function, divisor function, Euler's ϕ function, prime counting function, divergence of the sum of reciprocals of primes.

Quadratic reciprocity: The group structure of units of Z/nZ, n-th power residues, quadratic residues mod p, Legendre symbols, quadratic reciprocity law (proof included). Applications of quadratic reciprocity in Diophantine equations.

Cryptography: Caesar cipher, public key cryptography, the knapsack cryptosystem, applications of primitive roots to cryptography, the RSA cryptography.

Books Recommended:

1. D. M. Burton, Elementary Number Theory, 7th Ed., Mc Graw Hill, 2017.
2. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd Ed., Springer, 1998.

MULTI-DISCIPLINARY COURSE IN MATHEMATICS

(SEMESTERS I/II/III)

MDMA01: IKS VI--Ancient Indian Mathematics

Course Category	Course Name	Course Code	Credit	Marks			Weekly Distribution of Class Hours		
				Internal Marks	End Semester Marks	Total Marks	Lecture	Tutorial	Practical
Multidisciplinary	Ancient Indian Mathematics	MDMA01	3	15	60	75	3	0	0

Learning Objectives:

The primary objectives of this course are to:

- Understand Vedic mathematics.
- Grasp the contribution of Buddha and Jain religious on mathematics.
- Understand development of mathematics in Golden Period.
- Understand Kerala School of Mathematics.
- Learn the mathematical concepts in Indus valley civilization

Learning Outcomes:

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

- Recognize the Indian knowledge system in ancient India
- Recognize the glorious part of Indian mathematics including geometry and Astronomy
- Recognize Kerala school of Mathematics
- Understand the contribution of Indian Knowledge system towards the civilization.

Syllabus:

Mathematics in Indus valley Civilization:

Urban Planning and Geometry, Grid-based city layout: Right angles in buildings, perpendicular lines and rectangular construction. Standardized brick proportions (length : width : height = 4:2:1) , An understanding of ratios.

Standardized Weights and Measures; binary multiples (1, 2, 4, 8, 16, 32,…), Decimal system in larger weights (100, 200, 500 units, etc.), Measuring instruments precise to 1.6 mm, showing advanced understanding of linear measurement.

Water Management and Volumetric Understanding;, Flow control , fluid mechanics and capacity.

Seals and Symmetry; geometric patterns, rotational symmetry, and fractal-like repetitions.

Proto-Mathematics in Artifacts; Harappan symbols, numerical. Circular platforms, geometric pottery designs, and planned agricultural plots as practical mathematical thinking.

Mathematics in Vedic Period:

The Śulba Sūtras (or Śulvasūtras**)** under Vedāṅgas (limbs of the Vedas), under the part of Kalpa Sūtras, which deal with rituals**.** Geometry for constructing altars (vedis) for Vedic sacrifices**.** Geometry**,** measurement**,** and approximation in Sulba sutra**.**

Sulba Sūtras developed by Baudhāyana, Āpastamba, Katyayana, Mānava : Pythagorean Theorem, Use of 3:4:5 ratio, √2 Approximation, Area Constructions ,Transforming one shape into another of equal area, Other Geometry Tools, Unit Fractions and Proportions, Rope Geometry.

Pingala and Chandaḥśāstra, Binary numbers, combinatorics, metrics.

Applications of Vedic Mathematics in arithmetic (addition, subtraction, multiplication, division), algebra (equations, factorization) and geometry and trigonometry (to some extent).

Concept of zero and infinity in Buddhist literature:

Śūnya (Zero/ Emptiness) in Buddhism, Mathematical Evolution, śūnya as a placeholder and a number, Ananta or apramāṇa.

Concept of zero and infinity in Jainism:

Infinity (Ananta) in Jainism, infinite in time but finite in space, infinity into multiple types: śūnya in metaphysical debates; zero as a number in numerical notation systems**;** Infinity in number,Infinity in time, Infinity in space, Infinity in knowledge (ananta jñāna)

Concept of five infinites (pañcānanta):

Ananta jñāna (infinite knowledge), ananta darśana (perception), ananta virya (energy), ananta sukha (bliss), ananta āyu (life span in divine realms)

Golden Period of Indian Mathematics:

Āryabhaṭa and Āryabhaṭīya: Place value, zero, $\pi \approx 3.1416$, sine table, quadratic equations. Brahmagupta and Brāhmasphuṭasiddhānta: Astronomical models, trigonometry. Bhāskara-I: Commentaries on Āryabhaṭa, sine function approximations. Srīdhara and Patiganita: Rules of arithmetic, interest, and mansuration. Mahavira and Ganitasarasanghraha: Algebraic operations, fractions, permutations. Bhāskara II and Lilavati: several rules of algebra. Nārāyaṇa Paṇḍita:Magic square, combinatorics,algebraic identities.

Kerala School of Mathematics:

Madhava–Leibniz series, Madhava's Sine Table, Parameśvara and drik system, mean value of sine function**,** Karanapaddhati – astronomical handbook.Jyesthadeva and Yuktibhāṣā, proofs of series for π, sine, cosine and area under curves using summation. Śaṅkara Vāriyar and his commentaries on earlier works and his Contributed to arithmetic progressions**.**

Books Recommended:

1.Bibhutibhusan Datta and Avadesh Narayan Singh; History of Hindu Mathematics- Part I; Gyan Prakashan.

2.Bibhutibhusan Datta and Avadesh Narayan Singh; History of Hindu Mathematics- Part II; Gyan Prakashan.

3. George Gheverghese Joseph: Indian Mathematics;World Scientific.