The Kelkar Education Trust's
Vinayak Ganesh Vaze College of Arts, Science & Commerce
(Autonomous)

Mithaghar Road, Mulund East, Mumbai-400081, India
College with Potential for Excellence
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Syllabus for B. Sc. Third Year Programme

Mathematics

Syllabus as per Choice Based Credit System (NEP-2020)

(June 2025 Onwards)

Board of Studies in Mathematics

V.G Vaze College of Arts, Science and Commerce (Autonomous)

Submitted by

Department of Mathematics
Vinayak Ganesh Vaze College of Arts, Science and Commerce (Autonomous)
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The Kelkar Education Trust's

Vinayak Ganesh Vaze College of Arts, Science & Commerce

(Autonomous)

❖ **Syllabus as per Choice Based Credit System (NEP 2020)**

Syllabus for Approval

Subject: Mathematics

Sr. No.	**Heading**	**Particulars**
1	Title of Programme	**Third Year B. Sc. Mathematics: Semester V and VI**
2	Eligibility for Admission	The Second Year B.Sc. examination of this university with Mathematics as a Major or Minor subject or any other university recognized as equivalent thereto.
3	Passing marks	Minimum D Grade or equivalent minimum marks for passing at the Graduation level.
4	Ordinances/Regulations (if any)	---
5	No. of Years/Semesters	One year/Two semester
6	Level	U.G. Part-III : Level - 5.5
7	Pattern	Semester
8	Status	Revised
9	To be implemented from Academic year	2025-2026

Date: …………. **Signature:**

BOS Chairperson: ……………………….

Third Year B. Sc. Program in Mathematics (Level 5.5)

Semester	Core Course & Credits		NSQF Course & Credits	
Sem - V	**MAJOR**	No. of Lectures	**VSC/SEC**	No. of Lectures
	Mandatory* Credits 10 (5 x 2)		**VSC Credits 2**	
	Course 1 Cr. 2: Advanced Calculus	2L	Course 1 Cr. 2: (Latex for Scientific Writing) Practical	4L
	Course 2 Cr. 2: Linear Algebra	2L		
	Course 3 Cr. 2: Topology of Metric Spaces-I	2L		
	Course 4 Cr. 2: Integral Equations	2L		
	Course 5 Cr. 2: Practical (Practical Based on all Papers)	4L		
	Electives (selected anyone) Credits 4 (2+2)		**OJT/FP/CEP/CC/RP**	
	Course 1 Cr. 2: Introduction to Statistics	2L	**FP Credits 2**	
	Course 2 Cr. 2: Practical based on Introduction to Statistics	4L	Course 1 Cr. 2: Practical	4L
	Course 3 Cr. 2: Numerical Analysis -I	2L		
	Course 4 Cr. 2: Practical based on Numerical Analysis -I	4L		
	MINOR Credits 4 (2+2)			
	Course 1 Cr. 2: Mathematical Physics	2L		
	Course 2 Cr. 2: Practical based on Mathematical Physics	4L		
Sem - VI	**MAJOR**			
	Mandatory* Credits 10 (5 x 2)		**VSC Credits 2**	
	Course 1 Cr. 2: Complex Analysis	2L	Course 1 Cr. 2: Python Programming	4L
	Course 2 Cr. 2: Group Theory	2L		
	Course 3 Cr. 2: Topology of Metric Spaces-II	2L		
	Course 4 Cr. 2: Calculus of Variation	2L		
	Course 5 Cr. 2: Practical (Practical Based on all Papers)	4L		
	Electives (selected anyone) Credits 4 (2+2)		**OJT/FP/CEP/CC/RP**	
	Course 1 Cr. 2: Operational Research	2L	**OJT Credits 4**	
	Course 2 Cr. 2: Practical ()	4L	Course 1 Cr. 4: Practical	8L
	Course 3 Cr. 2: Numerical Analysis -II	2L		
	Course 4 Cr. 2: Practical ()	4L		
	MINOR Credits 2			
	Course 1 Cr. 2: Integral Transforms	2L		
Total Cumulative credits = **20 + 08 + 06 + 04 + 06 = 44 Credits**				
Exit option: *Award of UG Degree in Major and Minor with 132 credits OR continue with Major & Minor*				

B. Sc. Program in Mathematics: Cumulative Credit Structure

<table>
<tr><th rowspan="2">Level</th><th rowspan="2">Sem.</th><th colspan="2">MAJOR</th><th rowspan="2">MINOR</th><th rowspan="2">VSC</th><th rowspan="2">OJT / FP</th><th rowspan="2">Cum. Credits</th><th rowspan="2">Degree</th></tr>
<tr><th>Mandatory*</th><th>Electives Any one</th></tr>
<tr><td rowspan="4">5.5</td><td rowspan="2">Sem-V</td><td>For Mathematics</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Credits 10 (2+2+2+2+2)
Course 1 Cr. 2: Advanced Calculus
Course 2 Cr. 2: Linear Algebra
Course 3 Cr. 2: Topology of Metric Spaces I
Course 4 Cr. 2: Integral Equations
Course 5 Cr. 2: Practical (based on all papers)</td><td>Credits 4 (2+2)
Course 1 Cr. 2: Mathematical Physics &
Course 2 Cr. 2: Practical (Based on Mathematical Physics)
OR
Course1 Cr. 2: Numerical Analysis-I
&
Course 2 Cr. 2: Practical (Based on : Numerical Analysis-I)</td><td>Credits 4 (2+2)
Course 1: Cr. 2: Mathematical Physics
&
Course 2: Cr. 2: Practical based on Mathematical Physics</td><td>Credits 2
(Latex for Scientific Writing) Practical</td><td>Credits 2
Practical</td><td>22</td><td rowspan="4">UG Degree
After 3-Yr UG</td></tr>
<tr><td rowspan="2">Sem-VI</td><td>For Mathematics</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Credits 10 (2+2+2+2+2)
Course 1 Cr.2: Complex Analysis
Course 2 Cr.2: Group Theory
Course 3 Cr.2: Topology of Metric Spaces II
Course 4 Cr.2: Calculus of Variation
Course 5 Cr.2: Practical (Based on all Papers)</td><td>Credits 4 (2+2)
Course 1 Cr. 2: Operational Research &
Course 2 Cr. 2: Practical (based on Operational Research)
OR
Course1 Cr. 2: Numerical Analysis-II
&
Course 2 Cr. 2: Practical (Based on : Numerical Analysis-II)</td><td>Credits 2
Course 1: Cr. 2: Integral Transform</td><td>Credits 2
Practical Based on Major Courses</td><td>Credits 4</td><td>22</td></tr>
<tr><td colspan="2">Total Credits</td><td>20</td><td>08</td><td>06</td><td>04</td><td>06</td><td>44</td><td></td></tr>
</table>

Programme Educational Objectives

PEO1	Mathematical Foundation – Develop strong problem-solving and analytical skills in core mathematical concepts.
PEO2	Real-World Application – Apply mathematical methods in science, engineering, and other fields.
PEO3	Critical Thinking – Enhance logical reasoning and problem-solving abilities.
PEO4	Technology Integration – Utilize modern mathematical software and computational tools.
PEO5	Communication & Teamwork – Effectively communicate mathematical ideas and collaborate in teams.
PEO6	Lifelong Learning – Engage in continuous learning and research in mathematics.
PEO7	Ethical Responsibility – Apply mathematics responsibly in professional and societal contexts.

Programme Outcomes

Upon successful completion of the B.Sc. (Mathematics) course from Vaze College affiliated to Mumbai University, graduates can expect the following outcomes:

PO1	Mathematical Knowledge – Demonstrate a strong understanding of fundamental mathematical concepts and theories.
PO2	Problem-Solving Skills – Apply mathematical techniques to solve real-world problems efficiently.
PO3	Logical and Analytical Thinking – Develop critical thinking, reasoning, and analytical abilities.
PO4	Computational Proficiency – Use mathematical software, programming, and computational tools effectively.
PO5	Data Analysis and Modeling – Interpret and analyze data using mathematical and statistical methods.
PO6	Effective Communication – Convey mathematical ideas clearly through written and verbal communication.
PO7	Interdisciplinary Approach – Apply mathematical knowledge across various fields like physics, economics, and computer science.

Programme Specific Outcomes

PSO1	**Core Mathematical Proficiency** – Demonstrate expertise in algebra, calculus, differential equations, and other fundamental areas of mathematics.
PSO2	Computational and Analytical Skills – Apply mathematical and computational techniques to solve theoretical and practical problems.
PSO3	Mathematical Modeling – Develop and analyze mathematical models for real-world applications in science, engineering, and economics.
PSO4	**Data Interpretation and Statistics** – Use statistical and probabilistic methods to analyze and interpret data effectively.
PSO5	Software and Programming Proficiency – Utilize mathematical software (such as MATLAB, Maxima, or Python) for problem-solving and research.
PSO6	**Research and Higher Studies Readiness** – Build a strong foundation for advanced studies and research in mathematics and related fields.

The Detailed Semester and Course Wise Syllabus as follows:

The total minimum credits required for completing the B.Sc. in Mathematics is **132**

SEMESTER - V					
Code	**Course of Study – Major**	**L**	**T**	**P**	**Cr.**
VSMA300	Course 1 Cr. 2: Advanced Calculus	2	-	-	2
VSMA301	Course 2 Cr. 2: Linear Algebra	2	-	-	2
VSMA302	Course 3 Cr. 2: Topology of Metric Spaces-I	2	-	-	2
VSMA303	Course 4 Cr. 2: Integral Equations	2	-	-	2
VSMA304	Course 5 Cr. 2: Practical Based on Course 1 to 4	4	-	2	2
	Electives		-		
VSMA305	Course 1 Cr. 2: Introduction to Statistics	2	-	-	2
VSMA306	Course 2 Cr. 2: Practical based on Introduction to Statistics	4	-	2	2
VSMA307	Course 3 Cr. 2: Numerical Analysis -I	2	-	-	2
VSMA308	Course 4 Cr. 2: Practical based on Numerical Analysis -I	4	-	2	2
	VSC **Credits 2**		-		
VSMA309	Course 1 Cr. 2: Latex for Scientific Writing	4	-	2	2
	MINOR **Credits 4 (2+2)**		-		
VSMA310	Course 1 Cr. 2: Mathematical Physics	2	-	-	2
VSMA311	Course 2 Cr. 2: Practical based on Mathematical Physics	4	-	2	2
	FP **Credits 2**		-		
VSMA312	Course 1 Cr. 2: Practical	4	-	2	2
Total		32	-	10	**22**

***** **Note:** Students are allowed to select one elective out of two electives given in curriculum

SEMESTER – VI					
Code	**Course of Study – Major**	**L**	**T**	**P**	**Cr.**
VSMA350	Course 1 Cr. 2: Complex Analysis	2	-	-	2
VSMA351	Course 2 Cr. 2: Group Theory	2	-	-	2
VSMA352	Course 3 Cr. 2: Topology of Metric Spaces-II	2	-	-	2
VSMA353	Course 4 Cr. 2: Calculus of Variation	2	-	-	2
VSMA354	Course 5 Cr. 2: Practical (Practical Based on all Papers)	4	-	2	2
	Electives		-		
VSMA355	Course 1 Cr. 2: Operational Research	2	-	-	2
VSMA356	Course 2 Cr. 2: Practical based on Operational Research	4	-	2	2
VSMA357	Course 3 Cr. 2: Numerical Analysis -II	2	-	-	2
VSMA358	Course 4 Cr. 2: Practical (Numerical Analysis -II)	4	-	2	2
	VSC **Credits 2**		-		
VSMA359	Course 1 Cr. 2: Python Programming	4	-	2	2
	MINOR **Credits 2**		-		
VSMA360	Course 1 Cr. 2: Integral Transforms	2	-	-	2
VSMA361	**OJT** **Credits 4**		-		
	Course 1 Cr. 2: Practical	6	-	3	4
		30	-	11	**22**

***** **Note:** Students are allowed to select one elective out of two electives given in curriculum

Proposed Draft Syllabus for TY. B. Sc. Mathematics Semester V and VI

(Mathematics Specialization)

Choice Based Credit System (NEP 2020)

(To be implemented from the academic year, 2025-2026)

Semester – V

Paper I

Course Code: VSMA300

Credits: 2

ADVANCED CALCULUS

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Evaluate double, triple, line, and surface integrals using appropriate techniques and coordinate transformations.
2.	Apply fundamental theorems (Fubini's, Green's, Stokes', and Gauss Divergence) to simplify and interpret integrals in vector calculus.
3.	Analyze the properties of conservative fields and use integrals to compute physical quantities like area, volume, and flux.

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Compute double, triple, line, and surface integrals using various coordinate systems and techniques.
CO2	Apply Green's, Stokes', and Gauss Divergence Theorems to solve problems in vector calculus.
CO3	Interpret integrals in terms of physical applications such as area, volume, work, and flux.

COURSE CONTENT

Unit	Contents	No. of lectures
Unit I	**Multiple Integral and its Applications** Double Integrals – Definition, interpretation, and applications in volume calculation. Iterated Integrals & Fubini's Theorem – Evaluating double integrals over rectangular and general regions. Double Integrals in Polar Coordinates – Conversion from Cartesian to Polar, setting up limits, and evaluation. Triple Integrals – Definition, setup, and determining limits of integration in three-dimensional space. Triple Integrals in Cylindrical and Spherical Coordinates – Conversion and evaluation in different coordinate systems. Change of Variables in Multiple Integrals – Generalized coordinate transformations, Jacobian, and applications.	**10**

Unit II	**Line Integral** Review of Gradient, curl, divergence, and their significance. Parameterized paths in $\mathbb{R}^n$ and Smooth and piecewise smooth paths, closed paths, and orientation. Definition of Line integral of scalar and vector field over a piecewise smooth path and their Properties & Examples. Line integrals of gradient vector fields. Fundamental Theorem of Calculus for Line Integrals. Conservative vector fields: necessary and sufficient conditions. Green's Theorem & its applications to evaluation of line integrals.	**10**
Unit III	**Surface Integrals** Definition of Parameterized surfaces, Smooth equivalence and surface area. Definition and Properties of Surface integrals of scalar-valued functions, Surface integrals of vector fields. Gradient, curl, divergence, and basic identities. Stokes' Theorem (proof assuming Green's Theorem) and examples. Gauss Divergence Theorem. Examples and applications.	**10**

List of suggested Practicals:

1. Calculating Area and Volume
2. Integration in Polar, Cylindrical, and Spherical Coordinates
3. Evaluating Line Integrals
4. Verify and apply Green's Theorem.
5. Computing Surface Area and Surface Integrals
6. Stokes' and Gauss Divergence Theorems
7. Miscellaneous theoretical questions based on three units

Reference Books:

1. Thomas' Calculus – George B. Thomas, Maurice D. Weir, and Joel R. Hass
2. Calculus: Early Transcendentals – James Stewart
3. Vector Calculus – Jerrold E. Marsden and Anthony J. Tromba
4. Advanced Engineering Mathematics – Erwin Kreyszig
5. Mathematical Methods for Physicists – George B. Arfken and Hans J. Weber
6. Differential and Integral Calculus – Richard Courant

Paper II

Course Code: VSMA301

Credits: 2

LINEAR ALGEBRA

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand the foundational concepts of vector spaces, including subspaces, basis, and dimension, and apply these to real-world examples like $\mathbb{R}^n$, $\mathbb{R}[x]$and function spaces.
2.	Analyze linear transformations through their kernel, image, rank-nullity theorem, and matrix representation, including effects of basis changes.
3.	Explore inner product spaces by examining norms, orthogonality, projections, and the Gram-Schmidt process, with geometric and computational applications in $\mathbb{R}^2$, $\mathbb{R}^3$ and function spaces

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Understand real vector spaces, subspaces, basis, dimension and their properties.
CO2	Understand the notion of Linear transformations & Rank nullity theorem.
CO3	Know the properties of inner product spaces. Know the properties of linear transformation and isomorphism theorems & Apply Cauchy-Schwarz inequality for obtaining orthonormal basis using Gram-Schmidt orthogonalization.

COURSE CONTENT

Unit	Contents	No. of lectures
Unit I	**Vector Spaces** Vector Spaces Definition of a real vector space, Examples such as $\mathbb{R}^n$,$\mathbb{R}[x]$,$\mathcal{M}_{mxn}(\mathbb{R})$ space of all real valued functions on a non-empty set. Definition of a subspace of a vector space and examples. Properties of a subspaces, linearly independent/linearly dependent subsets of a vector space, linear span, Basis of a vector space, dimension of a vector space.	**10**
Unit II	**Linear Transformation** Definition of linear transformation, Kernel, Image of a linear transformation, Rank and Nullity of a linear transformation, and its properties, Rank nullity theorem and examples. Linear isomorphisms, inverse of a linear isomorphism. Representation of linear maps by matrices and effect under a change of basis, examples.	**10**
Unit III	**Inner Product Spaces** Dot product in $\mathbb{R}^n$. Definition of general inner product on a vector space over $\mathbb{R}$. Examples of inner product including the inner product	**10**

	$< f, g >= \int f(t)g(t)dt \;\; on \;\; C[-\pi, \pi]$ the space of continuous real valued functions on $[-\pi, \pi]$, Norm of a vector in an inner product space. Cauchy-Schwartz inequality, Triangle inequality, Orthogonality of vectors, Pythagoras theorem and geometric applications in $\mathbb{R}^2$, Projections on a line, the projection being the closest approximation, orthogonal complements of a subspace, Orthogonal complements in $\mathbb{R}^2$ and $\mathbb{R}^3$. Orthogonal sets and orthonormal sets in an inner product space, Orthogonal and orthonormal bases. Gram-Schmidt orthogonalization process, Simple examples in $\mathbb{R}^3$ and $\mathbb{R}^4$.	

List of suggested Practicals:

1.Vector space, linearly dependent / independent vectors.

2. Basis, Dimension of vector space.

3.Linear Transformation

4. Rank and Nullity of linear transformation.

5. Inner product spaces, examples. Orthogonal complements in $\mathbb{R}^2$ and $\mathbb{R}^3$.

6. Gram-Schmidt method

7. Miscellaneous Theoretical Questions based on full paper.

Reference Books:

1. Serge Lang: Introduction to Linear Algebra, Springer Verlag.
2. S. Kumaresan: Linear Algebra A geometric approach, Prentice Hall of India Private Ltd.
3. Gilbert Strang, Linear Algebra and its Applications, International Student Edition.
4. L. Smith, Linear Algebra, Springer Verlag.
5. A. Ramchandran Rao, P. Bhimashankaran; Linear Algebra Tata Mac Graw Hill.

Paper III
Course Code: VSMA302
Credits: 2

TOPOLOGY OF METRIC SPACES-I

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Conceptual understanding- definition & basics, open & closed sets, convergence & Continuity, Compactness, Completeness etc.
2.	Prove properties of metric spaces using rigorous mathematical reasoning.
3.	Solve problems involving the topology of metric spaces, such as open covers, closure, and interior of sets.
4.	Explore the role of metric spaces in real-world problems, such as optimization, analysis, and computer science.
5.	Understand how metric spaces provide the foundation for advanced mathematical concepts like normed vector spaces and Hilbert spaces.

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Define real numbers, identify the convergency and divergency of sequences, explain the limit and continuity of a function at a given point & construct the geometric model of the set of real numbers.
CO2	Define the existence of a sequence's limit, if there exists, find the limit & explain the notion of limit of a function at a given point and if there exists estimate the limit.
CO3	Define the notion of continuity and obtain the set of points on which a function is continuous & explain the notion of metric space. Use the open ball on metric spaces, construct the metric topology and define open-closed sets of the space

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit I	**Metric spaces** Definition, examples of metric spaces $\mathbb{R}$, $\mathbb{R}^2$, Euclidean space $\mathbb{R}^n$ with its Euclidean, sup and sum metric, $\mathbb{C}$ (complex numbers), the spaces l^1 and l^2 of sequences and the space $C[a, b]$, of real valued continuous functions on $[a, b]$. Discrete metric space. Metric subspaces, Product of two metric spaces. Open balls and open set in a metric space, examples of open sets in various metric spaces. Hausdorff property. Interior of a set. Properties of open sets. Structure of an open set in $\mathbb{R}$. Equivalent metrics.	**10**

	Distance of a point from a set, between sets, diameter of a set in a metric space and bounded sets. Closed ball in a metric space, Closed sets- definition, examples. Limit point of a set, isolated point, a closed set contains all its limit points, Closure of a set and boundary of a set.	
Unit II	**Sequences and Complete metric spaces** Sequences in a metric space, Convergent sequence in metric space, Cauchy sequence in a metric space, subsequences, examples of convergent and Cauchy sequence in finite metric spaces, $\mathbb{R}^n$ with different metrics and other metric spaces. Characterization of limit points and closure points in terms of sequences. Definition and examples of relative openness/closeness in subspaces. Definition of complete metric spaces, Examples of complete metric spaces, Completeness property in subspaces, Nested Interval theorem in $\mathbb{R}$, Cantor's Intersection Theorem, Applications of Cantors Intersection Theorem: The set of real Numbers is uncountable, Density of rational Numbers, Intermediate Value theorem:	**10**
Unit III	**Compact sets** Definition of compact metric space using open cover, examples of compact sets in different metric spaces $\mathbb{R}$, $\mathbb{R}^2$, $\mathbb{R}^n$, Properties of compact sets: A compact set is closed and bounded, (Converse is not true). Every infinite bounded subset of compact metric space has a limit point. A closed subset of a compact set is compact. Union and Intersection of Compact sets. Equivalent statements for compact sets in $\mathbb{R}$: Sequentially compactness property, Heine Borel property, Closed and boundedness property.	**10**

List of suggested Practicals:

1. Example of metric spaces, normed linear spaces
2. Sketching of open balls in $\mathbb{R}^2$ and open sets in metric spaces/ normed linear spaces, interior of a set, subspaces
3. Closed sets, sequences in a metric space
4. Limit points, dense sets, separability, closure of a set, distance between two sets.
5. Complete metric space
6. Cantor’s Intersection theorem and its applications
7. Miscellaneous theory questions from all unit

Reference Books:

1. S. Kumaresan, Topology of Metric spaces.
2. E. T. Copson. Metric Spaces. Universal Book Stall, New Delhi.
3. Expository articles of MTTS programme.

Paper IV
Course Code: VSMA303
Credits: 2

INTEGRAL EQUATIONS

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Identify and classify different types of integral equations (e.g., Volterra vs. Fredholm, first-kind vs. second-kind).
2.	Explain the connections between integral equations and differential equations.
3.	Solve simple integral equations analytically using methods such as: Successive substitutions, Successive approximations. Resolvent kernel methods. Laplace and Fourier transforms.
4.	Formulate and model physical, biological, and engineering problems as integral equations

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Understanding Integral Equations & Analytical Solution Techniques
CO2	Demonstrate knowledge of the theoretical foundation for the existence and uniqueness of solutions & implement numerical techniques, including quadrature methods, discretization, and iterative schemes, to approximate solutions of integral equations.
CO3	Applications of Integral Equations & Understand the properties of Riemann integrable functions, The applications of the fundamental theorems of integration.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit I	**Introduction of Integral Equation** Definition of Integral Equations and their classifications. Eigen values and Eigen functions. Special kinds of Kernel, Convolution Integral. The inner or scalar product of two functions. Reduction to a system of algebraic equations. Fredholm alternative, Fredholm theorem, Fredholm alternative theorem, an approximate method.	**10**
Unit II	**Solution of Fredholm equation** Method of successive approximations, Iterative scheme for Fredholm and Volterra Integral equations of the second kind. Conditions of uniform convergence and uniqueness of series solution. Some results about the resolvent Kernel. Application of iterative scheme to Volterra integral equations of the second kind. Classical Fredholm's theory, the method of solution of Fredholm equation, Fredholm's First theorem, Fredholm's second theorem, Fredholm's third theorem.	**10**

Unit III	**Solution of Volterra equation** Symmetric Kernels, Complex Hilbert space. An orthonormal system of functions, Riesz-Fisher theorem, A complete two-Dimensional orthonormal set over the rectangle a Fundamental property of Eigenvalues and Eigenfunctions for symmetric Kernels. Expansion in eigen functions and Bilinear form. Hilbert-Schmidt theorem and some immediate consequences. Definite Kernels and Mercer's theorem. Solution of a symmetric Integral Equation. Approximation of a general -Kernel (not necessarily symmetric) by a separable Kernel. The operator method in the theory of integral equations	**10**

List of suggested Practicals:

1.Analytical Solution of a Fredholm Integral Equation.

2.Numerical Solution Using the Trapezoidal Rule.

3.Application: Heat Conduction Problem.

4.Inverse Problem: Image Deblurring.

5.Eigenvalues of a Symmetric Kernel.

6.Properties of Riemann integral, non-Riemann integrable function.

7.Miscellaneous theoretical questions based on three units

Reference Books:

1. "Integral Equations" by F.G. Tricomi
2. "Elements of Integral Equations" by M.A. Khuri
3. "Integral Equations and Applications" by C. Corduneanu .

ELECTIVE COURSE

Semester – V

Paper V: Electives-1

Course Code: VSMA305

Credits: 2

(INTRODUCTION TO STATISTICS)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Provide a strong foundation in descriptive and inferential statistical methods.
2.	Develop skills in hypothesis testing and data interpretation.
3.	Equip students to use statistical methods in practical scenarios.

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	Understand and apply descriptive and inferential statistical methods.
CO2	Conduct and interpret hypothesis tests with confidence.
CO3	Use statistical reasoning to solve real-world problems.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit-1	**Foundations of Statistics**	**10**
	Introduction to Statistics and Real-Life Applications, Types of Data: Qualitative vs. Quantitative, Levels of Measurement, Data Collection and Sampling Techniques, Measures of Central Tendency: Mean, Median, Mode, Measures of Dispersion: Range, Variance, Standard Deviation.	
Unit-2	**Probability and Probability Distributions**	**10**
	Introduction to Probability: Basic Rules and Applications, Probability Distributions: Binomial Distribution, Normal Distribution and Its Properties, Concept of Population vs. Sample, Sampling Distributions	
Unit-3	**Inferential Statistics and Hypothesis Testing**	**10**
	Basics of Estimation: Point and Interval Estimates, Hypothesis Testing Basics: Null and Alternative Hypothesis Type I and Type II Errors, Significance Levels and p-values, One-Sample Hypothesis Tests (z-test, t-test), Two-Sample Hypothesis Tests (Independent and Paired t-tests), Chi-Square Test for Independence and Goodness-of-Fit.	

List of suggested Practicals:

1.Exploring Data and Measures of Central Tendency

2.Measures of Dispersion and Variability

3.Probability and Binomial Distribution

4.Normal Distribution and Sampling

5.Hypothesis Testing with One-Sample Tests

6.Chi-Square Test for Independence

Reference Books:

1.Fundamentals of Statistics by S.C. Gupta

2.Statistical Methods by S.P. Gupta

3.Probability, Statistics, and Random Processes by T. Veerarajan

4.Applied Statistics and Probability for Engineers" by R. Jayaprakash Reddy

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Paper V: Electives-2
Course Code: VSMA307
Credits: 2
(NUMERICAL ANALYSIS-I)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Provide a strong foundation in descriptive and inferential statistical methods.
2.	Develop skills in hypothesis testing and data interpretation.
3.	Equip students to use statistical methods in practical scenarios.

COURSE OUTCOME

Upon completing the course the student will be able to

CO1	Understand Newton-Raphson method, Secant method, Regula-Falsi method, and their rate of convergence.
CO2	Learn Iteration methods: Muller method, Chebyshev method, Multipoint iteration method and their rate of convergence.
CO3	Learn Doolittle and Crouts method, Choleskys method, Jacobi iteration method, Gauss-Siedal method and convergence analysis.

COURSE CONTENT

Unit-1	**Errors Analysis and Transcendental & Polynomial Equations**	**10**
	Measures of Errors: Relative, absolute and percentage errors. Types of errors: Inherent error, Round-off error and Truncation error. Taylor's series example. Significant digits and numerical stability. Concept of simple and multiple roots. Iterative methods, error tolerance, use of intermediate value theorem. Iteration methods based on first degree equation: Newton-Raphson method, Secant method, Regula-Falsi method, Iteration Method. Condition of convergence and Rate of convergence of all above methods	
Unit-2	**Transcendental and Polynomial Equations**	**10**
	Iteration methods based on second degree equation: Muller method, Chebyshev method, Multipoint iteration method. Iterative methods for polynomial equations; Descarts rule of signs, Birge-Vieta method, Bairstrow method. Methods for multiple roots. Newton-Raphson method. System of non-linear equations by Newton- Raphson method. Methods for complex roots. Condition of convergence and Rate of convergence of all above methods	
Unit-3	**Linear System of Equations**	**10**
	Matrix representation of linear system of equations. Direct methods: Gauss elimination method. Pivot element, Partial and complete pivoting, Forward and backward	

	substitution method, Triangularization methods-Doolittle and Crout's method, Choleskys method. Error analysis of direct methods. Iteration methods: Jacobi iteration method, Gauss-Siedal method. Convergence analysis of iterative method. Eigen value problem, Jacobis method for symmetric matrices Power method to determine largest eigenvalue and eigenvector.	

List of suggested Practicals:

1. Newton-Raphson method, Secant method, Regula-Falsi method, Iteration Method
2. Muller method, Chebyshev method, Multipoint iteration method
3. Descarts rule of signs, Birge-Vieta method, Bairstrow method
4. Gauss elimination method, Forward and backward substitution method,
5. Triangularization methods-Doolittles and Crouts method, Choleskys method
6. Jacobi iteration method, Gauss-Siedal method Eigen value problem: Jacobis method for symmetric matrices and Power method to determine largest eigenvalue and eigenvector
7. Miscellaneous theoretical questions from all units

Reference Books:

1. Kendall E. and Atkinson, An Introduction to Numerical Analysis, Wiley.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publications.
3. S.D. Conte and Carl de Boor, Elementary Numerical Analysis, An algorithmic approach, McGraw Hill International Book Company.
4. S. Sastry, Introductory methods of Numerical Analysis, PHI Learning.
5. Hildebrand F.B., Introduction to Numerical Analysis, Dover Publication, NY.
6. Scarborough James B., Numerical Mathematical Analysis, Oxford University Press, New Delhi.

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Semester – V

Paper : VSC

Course Code: VSMA309

Credits: 2

(LATEX FOR SCINTIFIC WRITING)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand the basics of LaTeX, its applications, and the process of preparing and compiling input files.
2.	Learn LaTeX syntax for formatting words, lines, paragraphs, and managing text through listing and tabbing.
3.	Develop skills to create and customize tables using various LaTeX environments.

COURSE OUTCOME

Upon completing the course the student will be able to

CO1	Create structured LaTeX documents with proper text formatting, alignment, and spacing.
CO2	Apply advanced features like emphasized fonts, sectional units, numbered item references, and tabbed text.
CO3	Design professional tables with adjustable columns, merged cells, rotated text, and customized formatting.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit-1	**Introduction to LaTeX**	**10**
	Definition and application of LaTeX, Preparation and Compilation of LaTeX input file, LaTeX Syntax, Keyboard Characters in LaTeX.	
Unit-2	**Formatting in LaTeX**	**10**
	Text and Math mode fonts, Emphasized and colored font, Sectional unit, Labeling and referring numbered item, Text alignment and quoted text, new lines and paragraphs, Creating and filling blank spaces, Producing dashes with text, Listing text, Tabbing text through the tabbing environment	
Unit-3	**Table Preparation and Beamer**	**10**
	Table through the tabular environment, Table through the tabular x environment, Vertical positioning of tables, Sideways (rotated) text in table, adjusting column width in table, Additional provision for customizing text in table, Merging rows and columns in table. Basics of Beamer.	

List of Practicals:

1. Introduction to LaTeX
2. Syntax and Keyboard characters in LaTeX
3. Fonts in LaTeX
4. Sections, labelling and text alignment in LaTeX
5. New lines, paragraphs, blank space and dashes in LaTeX
6. Listing text –I
7. Listing text –II
8. Tabbing text
9. Table through tabular environment
10. Table through the tabularx environment
11. Positioning text in table
12. Customizing text in LaTeX

Reference Books:

1. LaTeX in 24 Hours, A practical guide for scientific writing, Dilip Datta, Springer International Publishing, 2017.
2. LaTeX, A Document Preparation System, User's Guide and Reference Manual, Leslie Lamport, Addison-Wesley Publishing Company, Inc., 1994.
3. LaTeX Beginner's Guide, Stefan Kottwitz, Packt Publishing Ltd, 2011.
4. LaTeX and Friends, M.R.C. van Dongen, Springer-Verlag Berlin Heidelberg ,2012.

Semester – V
Paper: MINOR
Course Code: VSMA310
Credits: 2
(MATHEMATICAL PHYSICS)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Grasp the fundamental principles of vector calculus and matrix algebra.
2.	Understand the mathematical foundations essential for modeling physical phenomena.
3.	Apply vector calculus to analyze fields and flow systems in physics, such as electromagnetism and fluid dynamics.
4.	Utilize matrix algebra for solving systems of linear equations and performing linear transformations.
5.	Integrate mathematical tools into physics problems, including eigenvalue problems, gradient analysis, and coordinate transformations

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	**Vector Calculus and Applications** – Demonstrate proficiency in vector algebra, differentiation, and integration, including gradient, divergence, curl, and integral theorems, with applications in physics such as electromagnetism and fluid dynamics.
CO2	**Linear Algebra and Matrix Operations** – Apply matrix operations, determinants, eigenvalues, and eigenvectors to solve systems of linear equations and analyze physical transformations in quantum mechanics, stability analysis, and mechanical systems.
CO3	**Mathematical Methods in Physics** – Utilize vector calculus, linear algebra, and integral theorems to solve problems in electromagnetic field theory, heat flow, fluid dynamics, and coordinate transformations.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit-1	**Vector Calculus**	**10**
	Review of vector algebra: addition, subtraction, dot product, cross product, and their physical significance, Triple products and applications in physics. Gradient of a scalar field, its physical interpretation, and applications. Divergence and Curl of a vector field: properties, physical significance, and examples & Del operator and its operations in Cartesian coordinates. Line integrals: calculation and applications, Surface integrals:	

	flux across a surface & Volume integral: applications in physics. Statement and applications of Green's theorem, Gauss's divergence theorem, and Stokes' theorem & Use of the theorems in solving physics problems.	
Unit-2	**Matrix Algebra**	**10**
	Types of matrices: square, diagonal, identity, symmetric, skew-symmetric, and Hermitian matrices. Operations on matrices: addition, multiplication, and scalar multiplication. Properties of determinants & Calculation of inverses using adjoint and determinant methods. Definition and physical significance, Methods to find eigenvalues and eigenvectors & Applications in physics (e.g., quantum mechanics, stability analysis). Rotations, reflections, and scaling in two and three dimensions and Application to coordinate transformations in physics.	
Unit-3	**Applications in Physics**	**10**
	Electromagnetic field theory: Gradient, divergence, and curl in Maxwell's equations. Fluid dynamics: velocity field, circulation, and vorticity & Heat flow and diffusion equations. Systems of linear equations and their solutions using matrices, Matrix representation of linear transformations in quantum mechanics. Normal modes and vibrations in mechanical systems using eigenvalues and eigenvectors. Tensor algebra basics (if time permits) & Diagonalization of matrices and applications in simplifying physical systems.	

List of suggested Practicals:

1. Gradient, Divergence, and Curl: Compute and visualize gradient, divergence, and curl of vector fields.
2. Verification of Theorems: Verify Green's, Gauss's, and Stokes' theorems using integrals.
3. Matrix Operations and Inverses: Perform addition, multiplication, and inverse calculation of different types of matrices.
4. Eigenvalues, Eigenvectors, and Transformations: Compute eigenvalues, eigenvectors, and apply rotation, reflection, and scaling in physics.
5. Vector Calculus in Physics: Compute gradient, divergence, and curl in Maxwell's equations and fluid dynamics.
6. Matrix Methods in Physics: Solve linear systems, analyze quantum transformations, and study normal modes using eigenvalues.

Reference Books:

1. "Vector Calculus" by Jerrold E. Marsden and Anthony J. Tromba.
2. "Advanced Engineering Mathematics" by Erwin Kreyszig.
3. "Introduction to Linear Algebra" by Gilbert Strang.
4. "Matrices and Linear Algebra" by Hans Schneider and George Phillip Barker.
5. "Mathematical Methods for Physicists" by George B. Arfken and Hans J. Weber.

Proposed Draft Syllabus for TY. B. Sc. Mathematics Semester V and VI

(Mathematics Specialization)

Choice Based Credit System (NEP 2020)

(To be implemented from the academic year, 2025-2026)

Semester – VI

Paper I

Course Code: VSMA350

Credits: 2

COMPLEX ANALYSIS

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand how complex numbers provide a satisfying extension of the real numbers.
2.	Learn techniques of complex analysis that make practical problems easy (e.g. graphical rotation and scaling as an example of complex multiplication).
3.	Appreciate how mathematics is used in design (e.g. conformal mapping).
4.	Learn how to find the radius of convergence, disc of convergence.

Course Outcome

Upon completing the course, the student will be able to understand

CO1	**Complex Functions and Differentiation** – Understand the fundamental concepts of complex functions, limits, continuity, and differentiation, including Cauchy-Riemann equations and harmonic functions, with applications in mathematical physics.
CO2	**Complex Integration and Theorems** – Evaluate contour integrals using Cauchy's theorems, and the Cauchy integral formula, and apply them to solve problems in complex analysis.
CO3	**Series Expansions and Residue Theorem** – Analyze the convergence of sequences and series, apply Taylor and Laurent series, classify singularities, and use the residue theorem to evaluate complex integrals.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit I	**Analytic Functions** Functions of a Complex Variables, Limits, Theorems on limits, Limits involving the point at infinity, Derivatives of complex functions, Cauchy- Riemann Equations, Polar coordinates, Analytic functions, Harmonic functions.	**10**

Unit II	**Complex Integrals** Exponential function, logarithmic function, trigonometric functions, hyperbolic functions, and their properties, linear fractional transformations. Evaluating the contour integral of complex functions, Cauchy's integral theorem, Cauchy-Goursat theorem, Morera theorem, The Cauchy integral formula, consequences of the Cauchy integral formula, derivative of analytic functions.	**10**
Unit III	**Complex Power Series** Taylor's theorem for analytic functions, power series of complex numbers and related results, radius of convergence, disc of convergence, uniqueness of series representation, Laurent series, definition of isolated singularity, type of isolated singularities viz. removable, pole and essential defined using Laurent series expansion, Cauchy residue theorem and calculation of residue, applications of residues	**10**

List of suggested practicals:

1. Limit and continuity and sequence of complex numbers
2. Derivatives of complex functions, analytic & harmonic functions
3. Elementary functions and Mobius transformation
4. Cauchy integral formula & derivative of analytic function
5. Laurent series and singularities
6. calculation of residues and applications.
7. Miscellaneous theoretical questions based on three units

Reference Books:

1. J.W. Brown and R.V. Churchill, Complex Variables and Applications, International Student Edition, 2009.

2. S. Ponnusamy, Complex Analysis, (Second Edition Narosa).

3. L. V. Ahlfors, Complex Analysis, (3rd edition, McGraw Hill), 2000.

4. H. A. Priestley, Introduction to Complex Analysis (2nd edition (Indian), Oxford), 2006.

Paper II
Course Code: VSMA351
Credits: 2

GROUP THEORY

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand the definition and key concepts of groups, abelian groups, and subgroups.
2.	Differentiate between finite and infinite groups, including examples such as the Klein 4-group, symmetric groups S_n, and dihedral groups D_n.
3.	Learn the definition and properties of cyclic groups and cyclic subgroups, with examples like $\mathbb{Z}$, $\mathbb{Z}_n$ and $\mu(n)$
4.	Explore cosets, Lagrange's theorem, group homomorphisms, kernels, images, isomorphisms, and automorphisms with practical examples.

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Fundamentals of Group Theory – Understand the definition, types, and properties of groups, including abelian groups, symmetric groups, dihedral groups, and their role in mathematical structures and symmetries.
CO2	Subgroups and Cyclic Groups – Analyze subgroups, cyclic groups, their properties, and applications, including the Euler φ function and Lagrange's theorem with its consequences, such as Fermat's Little Theorem.
CO3	Group Homomorphisms and Isomorphisms – Explore group homomorphisms, kernels, images, isomorphisms, and automorphisms, with applications in structural transformations and symmetry analysis.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit I	**Groups and Subgroups** Definition of a group, abelian group, order of a group, Finite and infinite groups. Klein 4-group, The symmetric group Sn. The group of symmetries of a plane figure. The Dihedral group Dn as the group of symmetries of a regular polygon of n sides (for n = 3 ; 4). Subgroups, definition and examples, Necessary and sufficient condition for a non-empty subset to be a subgroup. The Centre of a group.	**10**

Unit II	**Cyclic Groups and Cyclic subgroups** Definition of a cyclic group, a finite group of order n is a cyclic group iff it contains an element of order n, subgroup of a cyclic group is cyclic. Examples of Z, Zn, and $\mu(n)$ as Cyclic groups. Properties of cyclic groups, Number of generators of a cyclic group, group of prime order is cyclic, Euler φ function.	**10**
Unit III	**Lagrange's Theorem and Group homomorphism** Definition of coset and its properties, Lagrange's theorem and consequences such as Fermat's Little theorem, Group homomorphisms Kernel and image of a group homomorphism, Group isomorphisms, Automorphisms of a group. inner automorphism. Examples and properties.	**10**

List of Suggested Practicals

1. Examples and properties of groups.
2. Group of symmetry of equilateral triangle, rectangle, square.
3. Subgroups.
4. Cyclic groups, cyclic subgroups, finding generators of every subgroup of a cyclic group.
5. Left and right cosets of a subgroup, Lagrange's Theorem.
6. Group homomorphisms, isomorphisms.
7. Miscellaneous Theoretical questions based on full paper.

Reference Books:

1. I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, Second edition.
2. N.S. Gopalakrishnan, University Algebra, Wiley Eastern Limited.
3. M. Artin, Algebra, Prentice Hall of India, New Delhi.
4. P.B. Bhattacharya, S.K. Jain, S. Nagpaul. Abstract Algebra, 2^{nd} edition, New Delhi.
5. J.B. Fraleigh, A first course in Abstract Algebra, Third edition, Narosa, New Delhi.
6. J. Gallian. Contemporary Abstract Algebra. Narosa, New Delhi.
7. Combinatorial Techniques by Sharad S. Sane, Hindustan Book Agency.
9. T. W. Hungerford. Algebra, Springer.
10. D. Dummit, R. Foote. Abstract Algebra, John Wiley & Sons, Inc.
11. I.S. Luther, I.B.S. Passi. Algebra. Vol. I and II

Paper III
Course Code: VSMA352
Credits: 2

TOPOLOGY OF METRIC SPACES-II

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Explore the role of metric spaces in real-world problems, such as optimization, analysis, and computer science.
2.	Understand how metric spaces provide the foundation for advanced mathematical concepts like normed vector spaces and Hilbert spaces.
3.	Develop the ability to think abstractly and work with general spaces beyond the Euclidean setting.
4.	Enhance problem-solving skills and logical reasoning within the framework of metric spaces.
5.	Build a foundation for further studies in analysis, topology, and related disciplines.

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Continuity and Fixed-Point Theorems – Understand the epsilon-delta definition of continuity in metric spaces, properties of continuous functions, contraction mappings, and fixed-point theorems with applications.
CO2	Connectedness and Path Connectedness – Analyze concepts of connected and disconnected metric spaces, continuity preserving connectedness, and path connectedness in $\mathbb{R}^n$ with applications to convex sets and connected components.
CO3	Sequences and Series of Functions – Examine pointwise and uniform convergence of function sequences, convergence tests like Weierstrass M-test, power series properties, and their applications in defining and analyzing classical functions.

COURSE CONTENT

Unit	Contents	No. of lectures
Unit I	**Continuous functions on metric spaces** Epsilon-delta definition of continuity at a point of a function from one metric space to another. Characterization of continuity at a point in terms of sequences, open sets and closed sets and examples, Algebra of continuous real valued functions on a metric space. Continuity of composite continuous function. Continuous function on compact metric space. Contraction mapping and fixed point theorem, Applications.	**10**

Unit II	**Connected sets** Separated sets- Definition and examples, disconnected sets, disconnected and connected metric spaces, Connected subsets of $\mathbb{R}$. A continuous image of a connected set is connected. Characterization of a connected space, viz. a metric space is connected if and only if every continuous function from X to $\{1, -1\}$ is a constant function. Path connectedness in $\mathbb{R}^n$, definition and examples. A path connected subset of $\mathbb{R}^n$ is connected, convex sets are path connected. Connected components.	**10**
Unit III	**Sequence and series of functions** Sequence of functions - pointwise and uniform convergence of sequences of real- valued functions, examples. Relation between Uniform convergence & pointwise convergence, series of functions, convergence of series of functions, Weierstrass M-test. Examples. Power series in $\mathbb{R}$ centered at origin and at some point in $\mathbb{R}$, radius of convergence, region (interval) of convergence, uniform convergence, term by-term differentiation and integration of power series, Examples. Uniqueness of series representation, functions represented by power series, classical functions defined by power series such as exponential, cosine and sine functions, the basic properties of these functions.	**10**

List of suggested practicals :

1. Compact sets in various metric spaces
2. Compact sets in $\mathbb{R}^n$
3. Continuity in a metric space
4. Uniform continuity, contraction maps, fixed point theorem
5. Connectedness in metric spaces
6. Path connectedness.
7. Miscellaneous theory questions on all units

Reference Books:

1. S. Kumaresan, Topology of Metric spaces.
2. E. T. Copson. Metric Spaces. Universal Book Stall, New Delhi.
3. Robert Bartle and Donald R. Sherbert, Introduction to Real Analysis, Second Edition, John Wiley and Sons.
4. Ajit Kumar, S. Kumaresan, Basic course in Real Analysis, CRC press 5. R.R.

Paper IV

Course Code: VSMA353

Credits: 2

CALCULUS OF VARIATION

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand the historical development and importance of calculus of variations in mathematics and physics.
2.	Formulate variational problems and apply the fundamental principles of calculus of variations.
3.	Derive and solve the Euler-Lagrange equation for basic variational problems with fixed and movable boundaries
4.	Solve real-world problems involving optimization of functionals in one or two variables.
5.	Analyze variational problems with free or constrained boundaries and interpret the physical significance of solutions.

Course Outcome

Upon completing the course, the student will be able to understand

CO1	Understand the origin and significance of calculus of variations & Formulate variational problems from physical and mathematical contexts
CO2	Derive and solve the Euler-Lagrange equation for basic variational problems & Interpret the results in terms of optimal solutions.
CO3	Handle variational problems with movable boundary conditions.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit I	**Introduction to Calculus of Variations** Historical background and motivation. Basic concepts: functional, extremals, and variations. Examples of variational problems: geodesics, brachistochrone problem, and minimal surfaces	**10**
Unit II	**Fundamental Concepts and the Euler-Lagrange Equation** Derivation of the Euler-Lagrange equation. Necessary conditions for an extremum. Examples and applications: shortest path and isoperimetric problem.	**10**
Unit III	**Variations with Fixed and Movable Boundaries** Transversality condition. Variational problems with end points not fixed. Examples with free boundaries	**10**

List of Practicals:

1. Solving Variational Problems: Find extremals for geodesics, the brachistochrone problem, and minimal surfaces.
2. Calculus of Variations Applications: Use functionals and variations to solve physics-based optimization problems.
3. Euler-Lagrange Equation: Derive and apply it to find extremals in variational problems.
4. Applications in Physics and Geometry: Solve shortest path and isoperimetric problems using the Euler-Lagrange equation.
5. Fixed vs. Movable Boundaries: Solve variational problems with and without fixed endpoints.
6. Transversality Condition Applications: Apply transversality conditions to free-boundary problems in physics and geometry.

Reference Books:

1. "Introduction to the Calculus of Variations" by Hans Sagan.
2. "Calculus of Variations" by I.M. Gelfand and S.V. Fomin.
3. "The Calculus of Variations" by Bruce van Brunt.

ELECTIVE COURSE

Semester – VI
Paper V: Electives-1
Course Code: VSMA355
Credits: 2
(OPERATIONAL RESEARCH)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand the Scope and Applications of Operations Research: Explore the historical background, scope, and importance of operations research in solving real-world industrial and business problems.
2.	Learn Optimization Techniques: Develop the ability to formulate and solve problems using techniques such as Linear Programming, Simplex Method, and Sensitivity Analysis.
3.	Master Decision-Making Tools: Gain proficiency in transportation and assignment problem-solving methods, network models, CPM, and PERT for efficient resource allocation and scheduling.
4.	Explore Advanced Concepts: Understand and apply advanced techniques like Integer Programming, Dynamic Programming, Game Theory, and Queueing Theory.

COURSE OUTCOME

Upon completing the course, the student will be able to

CO1	Problem-Solving Proficiency: Students will be able to formulate and solve optimization problems, including LPPs, transportation, and assignment problems, using appropriate methods. Effective Decision-Making Skills: Apply decision-making models under certainty, uncertainty, and risk to optimize resource allocation and project scheduling.
CO2	Competence in Advanced Techniques: Use advanced optimization methods, including Integer Programming and Game Theory, to solve multistage decision problems and strategic scenarios.
CO3	Practical Application of OR Tools: Demonstrate the ability to analyze real-world scenarios in logistics, finance, and operations using operations research tools and methodologies.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit-1	**Introduction to Operations Research**	**10**
	Overview of Operations Research Historical background, scope, and applications in industries. Linear Programming Problem (LPP) Formulation of LPP and graphical solutions. Simplex Method Concept, tabular approach, and basic feasible solutions. Duality in Linear Programming Dual problems and economic interpretation. Sensitivity Analysis Impact of parameter changes on the optimal solution.	

Unit-2	**Decision Making and Resource Allocation**	**10**
	Transportation Problems Formulation, methods (North-West Corner, Least Cost, Vogel’s Approximation). Assignment Problems Hungarian method and applications in workforce optimization. Network Models: Shortest Path Problem and Minimum Spanning Tree. Project Scheduling Critical Path Method (CPM) and Program Evaluation Review Technique (PERT). Decision Theory Decision-making under certainty, uncertainty, and risk.	
Unit-3	**Advanced Optimization Techniques and Applications**	**10**
	Integer Programming Formulation and branch-and-bound method. Dynamic Programming Concepts and applications in multistage decision problems. Game Theory Basics Two-person zero-sum games, saddle point, and mixed strategies. Queueing Theory Introduction, characteristics, and basic models. Real-World Case Studies and Applications Practical examples in logistics, finance, and operations.	

List of suggested Practical

1.Linear Programming Problem (LPP) using Graphical and Simplex Methods

2. Transportation Problem Optimization

3. Assignment Problem Using Hungarian Method

4. Network Models: Shortest Path and Minimum Spanning Tree

5. Project Scheduling with CPM and PERT

6. Game Theory and Queueing Models

Reference Books:

1. Operations Research: An Introduction by Hamdy A. Taha

2. Introduction to Operations Research by Frederick S. Hillier and Gerald J. Lieberman.

3. Operations Research: Principles and Practice by Ravindran, Phillips, and Solberg.

4. Operations Research by S.D. Sharma

5. Quantitative Techniques in Management by N.D. Vohra

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Paper V: Electives-2
Course Code: VSMA357
Credits: 2
(NUMERICAL ANALYSIS -II)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions to otherwise intractable mathematical problems.
2.	Apply numerical methods to obtain approximate solutions to mathematical problems.
3.	Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations.
4.	Analyze and evaluate the accuracy of common numerical methods.

COURSE OUTCOME

Upon completing the course the student will be able to

CO1	To provide the student with numerical methods of solving the non-linear equations, interpolation, differentiation, and integration.
CO2	To improve the student's skills in numerical methods by using the numerical analysis software and computer facilities.
CO3	To improve the student's skills in apply Trapezoidal and Simpson's rules, analyze error & convergence, and use composite methods for accuracy.

COURSE CONTENT

Unit-1	**Interpolation**	**10**
	Interpolating polynomials, Uniqueness of interpolating polynomials. Linear, Quadratic and Higher order interpolation. Lagrange's Interpolation. Finite difference operators: Shift operator, forward, backward and central difference operator, Average operator and relation between them. Difference table, Relation between difference and derivatives. Interpolating polynomials using finite differences Gregory-Newton forward difference interpolation, Gregory-Newton backward difference interpolation, Stirlings Interpolation. Results on interpolation error.	
Unit-2	**Polynomial Approximations and Numerical Differentiation**	**10**
	Piecewise Interpolation: Linear, Quadratic and Cubic. Bivariate Interpolation: Lagrange's Bivariate Interpolation, Newton's Bivariate Interpolation. Numerical differentiation:	

	Numerical differentiation based on Interpolation, Numerical differentiation based on finite differences (forward, backward and central), Numerical Partial differentiation	
Unit-3	**Numerical Integration**	**10**
	Numerical Integration based on Interpolation. Newton-Cotes Methods, Trapezoidal rule, Simpson's 1/3rd rule, Simpson's 3/8th rule. Determination of error term for all above methods. Convergence of numerical integration: Necessary and sufficient condition (with proof). Composite integration methods; Trapezoidal rule, Simpson's rule Numerical Solutions of initial value ODE's such as Taylor Series Method, Euler's Method, Modified Euler's Method, Runge- Kutta Methods of fourth order.	

List of suggested Practicals:

1. Linear, Quadratic and Higher order interpolation, Interpolating polynomial by Lagrange's Interpolation
2. Interpolating polynomial by Gregory-Newton forward and backward difference Interpolation and Stirling Interpolation.
3. Bivariate Interpolation: Lagrange's Interpolation and Newton's Interpolation
4. Numerical differentiation: Finite differences (forward, backward and central), Numerical Partial differentiation
5. Numerical differentiation and Integration based on Interpolation
6. Numerical Integration: Trapezoidal rule, Simpsons 1/3rd rule, Simpsons 3/8th rule Composite integration methods: Trapezoidal rule, Simpsons rule Euler's Method, Modified Euler's Method, Runge- Kutta Methods of second order.
7. Miscellaneous theory questions on all units

Reference Books:

1. Kendall E, Atkinson, An Introduction to Numerical Analysis, Wiley.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publications.
3. S.D. Conte and Carl de Boor, Elementary Numerical Analysis, An algorithmic approach, McGraw Hill International Book Company.
4. S. Sastry, Introductory methods of Numerical Analysis, PHI Learning.
5. Hildebrand F.B, Introduction to Numerical Analysis, Dover Publication, NY.
6. Scarborough James B., Numerical Mathematical Analysis, Oxford University Press, New Delhi.

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Semester -VI
Paper : SEC
Course Code: VSMA359
Credits: 2
(PYTHON PROGRAMMING)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Master the fundamentals of writing Python scripts and Learn core Python scripting elements such as variables and flow control structures.
2.	Discover how to work with lists and sequence data and Write Python functions to facilitate code reuse.
3.	Use Python to read and write files and Make their code robust by handling errors and exceptions properly.
4.	Work with the Python standard library and Explore Python's object-oriented features Use Python libraries to generate graphs, visualize 3D plots.

COURSE OUTCOME

Upon completing the course the student will be able to

CO1	Implement Conditionals and Loops for Python Programs.
CO2	Write, Test and Debug Python Programs.
CO3	Create visualizations and graphical representations of data and mathematical concepts using libraries like matplotlib.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit-1	**Introduction to Python**	**10**
	A brief introduction about Python and installation of anaconda. ii. Numerical computations in Python including square root, trigonometric functions using math and cmath module. Different data types in Python such as list, tuple and dictionary, If statements, for loop and While loops and simple programmes using these, User-defined functions and modules. Various use of lists, tuple and dictionary, Use of Matplotlib to plot graphs in various formats.	
Unit-2	**Advanced topics in Python**	**10**
	Classes in Python, Use of Numpy and Scipy for solving problems in linear algebra and calculus, differential equations, Data handling using Pandas.	

Unit-3	**Iterations and Conditional statements**	**10**
	Conditional and alternative statements, Chained and Nested Conditionals, Tables using While Functions, User defined functions, Parameters and arguments, Installation of numpy, matplotlib packages, Graphs plotting of functions, Different formats of graphs, PyDotPlus (Scalable Vector Graphics), PyGraph viz. Decorate Graphs with Plot Styles and Types, Polar charts: Navigation Toolbar with polar plots, Control radial and angular grids, Three-dimensional Points and Lines, Three-dimensional Contour Plots, Wireframes and Surface Plots.	

List of Practicals:

1.Introduction to Python

2.Python Data Types

3.Control statements in Python

4.Control Structures: If Statements,

5.Loops: For and While

6.User-Defined Functions

7.Data Visualization with Matplotlib

8.Classes and Objects in Python

9.Using Numpy and Pandas

10.Graph plotting 2D & 3D

Reference Books:

1. Fundamentals of Python First programs 2nd edition - Kenneth A Lambert, Cengage,
2. Doing Math with Python - Amit Saha, No starch Press,
3. Problem solving and Python programming- E. Balgurusamy, Tata McGraw Hill.
4. Python: Notes for Professionals, Goalkicker.com, Free Programming books.

Semester – VI
Paper: MINOR
Course Code: VSMA360
Credits: 2
(INTERGRAL TRANSFORMS)

Course Learning Objectives

Upon completion of the course the student will be able to understand

1.	Understand the fundamental concepts of Laplace and Fourier transforms, including their definitions, kernels, and conditions for existence.
2.	Apply the properties of Laplace and Fourier transforms, such as linearity, shifting, scaling, and convolution, to solve differential and integral equations
3.	Master the techniques for calculating the Laplace and inverse Laplace transforms of elementary and complex functions using properties and methods like partial fraction decomposition.
4.	Explore the applications of Fourier transforms in solving problems related to signal processing, heat conduction, and partial differential equations.

COURSE OUTCOME

Upon completing the course the student will be able to

CO1	Solve complex problems involving Laplace transforms and their inverses, leveraging the associated properties and theorems.
CO2	Analyze and solve engineering and mathematical problems using Fourier transforms and their properties.
CO3	Demonstrate proficiency in using Laplace and Fourier transforms to handle real-world applications, such as modeling dynamic systems and analysing signals.

COURSE CONTENT

Unit	**Contents**	No. of lectures
Unit-1	**Laplace transform and Their Basic Properties**	10
	Basic concept & Definition of Integral Transform, Definition of the Laplace transform, Kernel of Laplace Transform, Definition of Sectional or piecewise continuity& Functions of exponential order, Sufficient conditions for existence of Laplace transform, Laplace transforms of elementary functions. Some important properties of Laplace transforms: Linearity property, first translation or shifting property, second translation or shifting property, change of scale property, Laplace	

	transform of derivatives, Laplace transform of integrals, Multiplication by t, Division by t.	
Unit-2	**Inverse Laplace Transform**	10
	Definition of inverse Laplace transforms, Uniqueness of inverse Laplace transform. Inverse Laplace transform of some functions. Some important properties of inverse Laplace transforms. Linearity property, first translation or shifting property, second translation or shifting property, change of scale property, Inverse Laplace transform of derivatives, Inverse Laplace transform of integrals, Multiplication by s^n , Division by s. Convolution Theorem, Partial fraction Method.	
Unit-3	**Fourier Transforms and Its Applications**	10
	Definition, Fourier integral, Fourier transform, inverse transform, Fourier transform of derivatives, convolution, Parseval's theorem, Applications.	

Reference Books:

1. Murray R. Spiegel, Schaum's Outline Series, Theory and Problems of Laplace Transforms, Mc Graw Hill Ltd, New York, 1965.
2. Lokenath Debnath and Dambaru Bhatta, Integral Transforms and Their Applications, Second Edition, C. R. C. Press, London, 2007.
3. Phil Dyke, An Introduction to Laplace Transforms and Fourier Series, Second Edition, Springer-Verlag London, 2014.
4. Joel L. Schiff, The Laplace Transform: Theory and Applications (Undergraduate Texts in Mathematics), Springer.
5. E. Kreyszig, "Advanced Engineering Mathematics", 10th Edition, John & Wiley Sons, U.K., 2016.

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