DEPARTMENT OF MATHEMATICS
PONDICHERRY UNIVERSITY

CURRICULUM FOR

FOUR YEAR BS HONOURS / WITH RESEARCH
&
FIVE YEAR INTEGRATED M. Sc.

IN MATHEMATICS

UNDER NATIONAL EDUCATION POLICY (NEP-PU)
Regulation-April 2023

(academic year 2023-24 onwards)

Year	Focus of the Course Structure and Exit Options
First-year	• Should equip students to take up advanced courses/ specialized coursework, • To choose Disciplinary/interdisciplinary course of their interest in the prospective professional field. *Exit Options* : Students exiting the program after securing 40 credits will be awarded a Certificate in Mathematics, provided they secure four credits in work-based vocational courses offered during the summer term or internship/apprenticeship.
Second-year	• Pre-requisite for advanced-level major courses. *Exit Options* : Students exiting the program after securing 80 credits will be awarded a Diploma in Mathematics, provided they secure an additional four credits in work-based vocational courses offered during the summer term or internship / Apprenticeship.
Third-year	• Disciplinary/interdisciplinary course study for the award of the degree. *Exit Options* : Students who want to undertake a 3-year UG program will be awarded a B.Sc. (Mathematics) degree upon securing a minimum of 122 credits. The internship is included as the Major 11 course.
Fourth-year	• Lectures with seminars, term papers, labs, hands-on internships, research projects, etc. • Research methodology / Statistics course for UG with Research *Exit Options* : Students will be awarded a B.S (Mathematics Honours) degree provided they secure 164 credits. The Honours students not undertaking research projects will do 3 courses for a total of 12 credits in lieu of a research project.
Fifth-year	Advanced or specialization subjects will be the focus. The candidates can choose a dissertation project if they score a CGPA of 7.5 or higher. Others can take three courses for 12 credits in place of the research project. At the end, the candidate will be awarded an MSc (Mathematics) degree subject to fulfilment of the stipulated number of credits

Semester-I

Course Code	Type	Credits	Title	Offered by
MATH 1110	MAJOR -1	4	Calculus	Math
STAT	Minor -1	4	Descriptive Statistics (suggested)	Stat
PHYS	Multi-Disciplinary-1	3	MDC*-1 Science and Society (suggested)	Phy
	Ability Enhancement -1	3	English – I	Eng
STAT	Skill Enhancement -1	3	Data Analysis with Excel-I	Stat
	Value Added- 1	2	Understanding India	Hist
	Value Added-2	2	Environmental Sciences	Envi
Semester Credits		**21**		

Semester-II

Course Code	Type	Credits	Title	Offered by
MATH 1210	MAJOR -2	4	Matrices and Theory of Equations	Math
STAT	Minor -2	4	Probability Theory (suggested)	Stat
	Multi-Disciplinary-2	3	MDC*-2	
	Ability Enhancement -2	3	English – 2	Eng
STAT	Skill Enhancement -2	3	Data Analysis with Excel-II	Stat
	Value Added- 3	2	Health and well Being	Ph-Edu
	Value Added-4	2	Digital Technologies	Comp
Semester Credits		**21**		

Semester-III

Course Code	Type	Credits	Title	Offered by
MATH 2110	MAJOR -3	4	Introduction to Real Analysis-I	Math
MATH 2120	MAJOR -4	4	Elements of Discrete Mathematics	Math
STAT	Minor -3	4	Distribution Theory(suggested)	Stat
	Multi-Disciplinary-3	3	MDC*-3	
	Ability Enhancement -3	3	Modern Indian Language-1	Language
STAT	Skill Enhancement -3	3	Exploratory DATA Analysis using R	Stat
Semester Credits		**21**		

MDC*: In each semester select any one course from the bouquet of **multi-disciplinary courses.** Minimum three courses have to be completed. But, exactly one course from any of the following categories: -
1. Natural Sciences/Physical Sciences 2. Statistics/Computer Applications 3. Lib. Information and Media Sciences 4. Commerce and Management 5. Humanities and Social Sciences.

Semester-IV

Course Code	Type	Credits	Title	Offered by
MATH 2210	MAJOR -5	4	Introduction to Real Analysis-II	Math
MATH 2220	MAJOR -6	4	Group Theory	Math
MATH 2230	MAJOR -7	4	Elements of Differential Equations	Math
STAT	Minor -4	4	Sampling Theory (suggested)	Stat
	Ability Enhancement -3	3	Modern Indian Language-2	Language
	Community Engagement	2	NSS/NCC	NSS
Semester Credits		**21**		

Semester-V

Course Code	Type	Credits	Title	Offered by
MATH 3110	MAJOR -8	4	Topology of Metric Spaces	Math
MATH 3120	MAJOR -9	4	Ring Theory	Math
MATH 3130	MAJOR -10	4	Multivariable Calculus	Math
PHYS	Minor -5	4	Newtonian Mechanics and waves (suggested)	Physics
MATH 3140	MAJOR- 11 (SEC-4)	4	Internship/Comprehensive Exam with Vivo voce	Maths
Semester Credits		**20**		

Semester-VI

Course Code	Type	Credits	Title	Offered by
MATH 3210	MAJOR -12	4	Fundamentals of Complex Analysis	Math
MATH 3220	MAJOR -13	4	Introduction to Linear Algebra	Math
MATH 3230	MAJOR -14	4	Graph Theory	Math
MATH 3240	MAJOR- 15	4	Linear Programing	Maths
PHYS	Minor -6	4	Thermal Physics (suggested)	Physics
Semester Credits		**20**		

Semester-VII

Course Code	Type	Credits	Title	Offered by
MATH 4110	MAJOR -16	4	Advanced Algebra	Math
MATH 4120	MAJOR -17	4	Topology	Math
MATH 4130	MAJOR -18	4	Differential Equations and Special functions	Math
MATH 41*1	Minor -7	4	From Annexure I	Math
MATH 41*1	Minor -8	4	From Annexure I	Math
Semester Credits		**20**		

Semester-VIII

Course Code	Type	Credits	Title	Offered by
MATH 4210	MAJOR -19	4	Advanced Real Analysis	Math
MATH 4220	MAJOR -20	4	Advanced Linear Algebra	Math
Ability Enhancement -4				
MATH 4213		12	Research Project Dissertation	Math
OR				
MATH 4211	Minor -9	4	Complex Analysis	Math
MATH 4221	Minor -10	4	Measure and Integration	Math
MATH 42*1	Minor -11	4	From Annexure I	Math
Semester Credits		**20**		

Semester-IX

Course Code	Type	Credits	Title	Offered by
MATH 5110	MAJOR -21	4	Functional Analysis	Math
MATH 5120	MAJOR -22	4	Partial Differential Equations	Math
MATH 51*1	Minor -12	4	From Annexure II	Math
MATH 51*1	Minor -13	4	From Annexure II	Math
MATH 51*1	Minor -14	4	From Annexure II	Math
Semester Credits		**20**		

<u>**Semester-X**</u>

Course Code	Type	Credits	Title	Offered by
MATH 52*1	Minor -15	4	From Annexure II	Math
MATH 52*1	Minor -16	4	From Annexure II	Math
Ability Enhancement -5				
MATH 5213		12	Research Project Dissertation	Math
OR				
MATH 52*1	Minor -17	4	From Annexure II	Math
MATH 52*1	Minor -18	4	From Annexure II	Math
MATH 52*1	Minor -19	4	From Annexure II	Math
Semester Credits		**20**		

LIST OF MINORS FOR 4th Year (ANNEXURE - I)

Course Code	Type / Semester	Credits	Title	Offered by
MATH 4111	Minor	4	Cryptography	Math
MATH 4121	Minor	4	Numerical Analysis	Math
MATH 4131	Minor	4	Number Theory	Math
MATH 4211	Minor	4	Calculus of Variations	Math
MATH 4221	Minor	4	Galois Theory	Math
MATH 4231	Minor	4	Lattice Theory	Math

LIST OF MINORS FOR 5th Year (ANNEXURE - II)

Course Code	Type / Semester	Credits	Title	Offered by
MATH 5111	Minor	4	Differential Geometry	Math
MATH 5121	Minor	4	Numerical Analysis for Ordinary Differential Equations	Math
MATH 5131	Minor	4	q-Series in Number Theory	Math
MATH 5141	Minor	4	Integral Transforms and Their Applications	Math
MATH 5151	Minor	4	Wavelet Theory and Applications	Math
MATH 5161	Minor	4	Graphs and Algebra	Math
MATH 5171	Minor	4	Probability and Statistics	Math
MATH 5211	Minor	4	Algebraic Number Theory	Math
MATH 5221	Minor	4	Advanced Topics in Topology and Analysis	Math
MATH 5231	Minor	4	Advanced Topology	Math
MATH 5241	Minor	4	Commutative Algebra	Math
MATH 5251	Minor	4	Discrete Dynamical Systems	Math
MATH 5261	Minor	4	Advanced Special Functions	Math
MATH 5271	Minor	4	Advanced Functional Analysis	Math
MATH 5281	Minor	4	Non-Commutative Rings and Representations	Math
MATH 5291	Minor	4	Algebraic Graph Theory	Math

ELIGIBILITY FOR LATERAL ADMISSION

Every student seeking admission in any year of the 5- year Integrated Master's program of the Department of Mathematics should have cleared the NTA_CUET entrance test after the 10+2 higher secondary schooling with Mathematics, Physics and Chemistry. Lateral entry will be governed under the PU-NEP Regulation April 2023 and its subsequent amendments.

MULTIDISPLINARY COURSE

Course Code	Type / Semester	Credits	Title	Offered by
MATH 1112	Minor / odd	4	Basic Mathematics	Math

MINOR COURSES OFFERED BY THE MATHEMATICS DEPARTMENT (For Science Department Students)

These courses are designed for students from Statistics, Physics and etc. These courses will be floated depending on the number of students registering and the availability of the faculty.
The number of students may be restricted depending on the available classroom facility and first-cum-first serve basis.

Course Code	Type / Semester	Credits	Title	Offered by
MATH 1111	Minor / odd	4	Basic Calculus	Math
MATH 1211	Minor / even	4	Basic Algebra and Theory of Equations	Math
MATH 2111	Minor / odd	4	Fundamentals of Real Analysis	Math
MATH 2211	Minor / even	4	Introduction to Differential Equations	Math
MATH 3111	Minor / odd	4	Calculus of several variable	Math
MATH 3211	Minor / even	4	Introduction to Linear Algebra	Math
MATH 4111	Minor / odd	4	Vector Calculus	Math
MATH 4211	Minor / even	4	Introductory Complex Analysis	Math

PONDICHERRY UNIVERSITY

RAMANUJAN SCHOOL OF MATHEMATICAL SCIENCES

DEPARTMENT OF MATHEMATICS

NEP COMPLIANT CURRICULUM & SYLLABI

for the
FOUR YEAR BS HONOURS / WITH RESEARCH
&
FIVE YEAR INTEGRATED M. Sc.

IN MATHEMATICS

to be implemented

WITH EFFECT FROM THE ACADEMIC YEAR

(2023-24 onwards)

Semester-I

MAJOR-1 **MATH 1110: CALCULUS** **(4 CREDITS)**

Course Objectives:

1. Able to analyze the derivatives and anti-derivatives of functions.
2. To understand the concept of applications of derivatives and integration

	Course Outcome
CO 1	Analyse the methods and application of differentiation
CO 2	To find asymptotes and draw free hand diagram of a given function
CO 3	Analyse the methods and application of integration

Unit I: (Sections: 3.2-3.9, 4.1, 4.3, 4.4)
Derivative of standard functions, Application of derivatives - Increasing decreasing functions - Maxima minima, Test of concavity& convexity point of inflexion.

Unit II: (Sections: 2.6, 4.2, 10.8, 11.3, 11.4, 13.4)
Mean value theorems, Taylor theorem, Maclaurin's theorem, Polar coordinates and curvature, Asymptotes, Graphing in polar co-ordinates.

Unit III: (Sections: 5.1, 5.2, 5.3, 5.4, 5.5)
Definite integrals - Properties of definite integrals - Integral as the limits of a sum- Evaluation of integrals- Area and the mean value theorem, fundamental theorem of calculus , Substitution in definite integrals.

Unit IV: (Sections: 8.1, 8.2, 8.3, 8.4, 8.5)
Integration by parts, Integration of rational fractions-Reduction formulas- $\sin^n x$, $\cos^n x$, $\tan^n x$, $\cot^n x$, $\sec^n x$, $\mathrm{cosec}^n x$, $\cos^m x \cos nx$, $\cos^m x \sin nx$, $\sin^n x \cos^m x$.

Unit V: (Sections: 5.6, 6.1, 6.2, 6.3, 6.4)
Areas between curves, Volume using cross section- Finding volume by slicing, Volumes of solids of revolution - Disk and washers- Cylindrical shell-Arc length-- Areas of surface of revolution.

Text Book

1. George B.Thomas, Maurice D.Weir and Joel Hass, Thomas' Calculus 12th Edition, Pearson Education, 2015.

Reference Books

1. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Vol.I, Springer 1999.
2. Serge Lang A First course in Calculus 5th edition, Springer, 1999.
3. N. P. Bali, Integral Calculus, Laxmi Publications, Delhi 1991.
4. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Volumes I & II Springer, SIE, 2004.
5. Serge Lang A First course in Calculus 5th edition, Springer, 1999.

Semester-II

MAJOR-2 MATH 1210: MATRICES AND THEORY OF EQUATIONS
(4 CREDITS)

Course Objectives:

1. To introduce the idea of matrices and to learn about the algebra of matrices
2. To solve system of linear equations using matrix Theory

	Course Outcome
CO 1	To learn the relation between the co-efficient and roots of polynomial equations.
CO 2	To learn various methods for solving polynomial equations and study the nature & position of roots.
CO 3	Analytic Methods for solving the polynomial equation of degrees 3 & 4.

Unit I: (Sections 1.1, 1.2, 1.3,1.4,1.5 of [1])
Linear systems - Matrices - Dot product and Matrix multiplication - Properties of Matrix operation, Matrix transformations.

Unit II: (Sections 1.6,1.7,1.8[1])
Solutions of Linear systems of equations - Row echelon from reduced row echelon form – Polynomial interpolation - The inverse of a Matrix. - Linear Systems and inverses - LU- Factorization Method.

Unit III: (Sections 5.1,5-2,.5.3 of [2])
Division algorithm - Relation between roots and coefficients - Sum of the powers of the roots.

Unit IV: (section 5.4,5.5,5.6 ,5.7 of [2])
Reciprocal equations - Transformation of equations: - Multiple roots - Nature of position of roots - Sturm's Theorem.

Unit V: (Sections 5.8,5.9,5.10 of [2])
Cardan’s Method for solving Cubic equations – Ferrari’s Method for solving biquadratic equations - New Newton's Method- Horner's Method

Text Books

1. Bernard Kolman Drid R. Hill, Introductory Linear Algebra, (8e),Pearson India (2011)
2. S. Arumugam and A Thangaand Isaac, Set Theory Number System and Theory of Equations, New Gamma publishing house(1997.).

References:

1. Theory of Equations, Hari Kishan, Atlantic Publishers, 2022

2.Theory of Equations, Lalji Prasad, New Revised Edition, 2016

Semester-III

MAJOR-3 MATH 2110: INTRODUCTION TO REAL ANALYSIS – I

Course Objectives: **(4 CREDITS)**

1. To study the importance of the LUB property of the real number system
2. To study the property of convergence sequence

	Course Outcome
CO 1	To discuss about the Bolzano Weierstrass theorem and recursive sequences
CO 2	To study about convergence of infinite series and various tests of convergence
CO 3	To understand the algebra of convergent series and rearrangement of infinite series

Unit I: (Sections 1.1, 1.2 and 1.3)

Algebra of the Real Number system – Upper and lower bounds – LUB property and its applications – Archimedean property – Greatest integer function – Density of rational numbers – Existence of n^{th} roots of positive real numbers – Nested intervals theorem.

Unit II: (Sections 1.4, 2.1, 2.2, 2.3 and 2.4)

Absolute value and Triangle Inequality – Subsets of R defined by inequalities – Convergent sequences – Definition and examples – Properties of algebra of limits of sequences – Bounded sequences – Sandwich Lemma – Cauchy sequences – Cauchy completeness of R - Monotone sequences – Geometric sequence – The number e - Nested intervals theorem.

Unit III: (Sections 2.5, 2.6, 2.7 and 2.8)

Some important limits – Cesaro's Theorem – Sequences diverging to $+\infty$. – Existence of a monotone sequence of a real sequence – Bolzano Weierstrass Theorem – Sequences definedrecursively.

Unit IV: (Sections 5.1 and 5.2)

Convergence and sum of an infinite series – Geometric series – Cauchy criterion – Algebra of convergent series – Absolutely convergent series – Comparison Test – Harmonic p-series – D'Alembert's ratio Test – Cauchy's Root Test – Integral Test – Cauchy's Condensation Test – Abel's Summation by parts Formula – Dirichlet's Test – Leibmitz Test for alternating series.

Unit V: (Section: 5.3 and 5.4)

Rearrangement of an infinite series – Definition and examples – Riemann's Theorem – Cauchy product of two infinite series – Merten's Theorem – Abel's Theorem on Cauchy product – Existence of decimal expansion – characterization and rational numbers.

Text Book:

1. Ajith Kumar and S.Kumaresan, ***A Basic Course in Real Analysis***, CRC Press (2014)

Reference Books:

1. Robert G. Bartle, Donald R. Sherbert, *Introduction to Real Analysis*; John Wiley and sons (Fourth Edition).
2. Kenneth A. Ross, *Elementary Analysis : The Theory of Calculus*, springer , 2e (2013).
3. Ajithkumar,S.Kumaresan, Bhasa Kumar Sarma , *A Foundation Course in Mathematics*, Narosa– 2018.

MAJOR-4 MATH: 2120: ELEMENTS OF DISCRETE MATHEMATICS
(4 CREDITS)

Course Objectives:

1. Able to understand the concepts of sets and determine whether a relation is a function and identify the domain and range of a function.
2. Understand the ideas of the basis step and the inductive step in a proof by Mathematical induction and recurrence relations

	Course Outcome
CO 1	To understand the basic concepts of Permutations and combinatorics
CO 2	To familiarize the applications of Difference sequences and Catalan numbers.
CO 3	To understand the concepts and significance of lattices and Partition of numbers.

Unit I: (Sections: 0.1, 0.2, 1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 2.4, 2.5)
Statements – Compound Statements – Contrapositive statements – Proofs in Mathematics (Types of proofs) – Direct proofs – Proof by cases – Proof by contradiction – Logic – Truth tables – The Algebra of Propositions – Logical arguments –Sets – Operations on sets – Binary relations – Equivalence relations – Partial orders.

Unit II: (Sections: 3.1, 3.2, 3.3, 4.1, 4.2, 4.3)
Functions – Inverses and composition – One-to-one correspondence and the cardinality of a set – The Integers – The Division algorithm – Divisibility – The Euclidean Algorithm – Prime numbers.

Unit III: (Sections: 5.1, 5.2, 5.3, 5.4, 6.1, 6.2)
Mathematical induction – Weak form and strong form – Recursively defined sequences – Solving recurrence relations – The characteristic polynomials – Solving recurrence relations – Generating functions – The principle of inclusion-Exclusion – The addition and multiplication rules.

Unit IV: (Sections: 6.3, 7.1, 7.2, 7.5, 7.6, 7.7)
The pigeonhole principle–Permutations – Combinations –Repetitions – Derangements – The binomial theorem.

Unit V: (Sections: 8.1, 8.2, 8.3, 8.4)
What is an Algorithm – Complexity – Searching and sorting – Enumeration of permutation and combination.

Text Books

Edgar G. Goodaire, Michael M. Parmenter, Discrete Mathematics with Graph Theory (Third Edition), PHI Learning Private Ltd., New Delhi - 2011.

Reference Books

1. Richard Johnson bauth, Discrete Mathematics, 5th Edition, Pearson Education Asia, New Delhi, 2002.
2. Ralph. R. Grimaldi - Discrete and Combinatorial Mathematics: An applied Introduction - 4th Edition, Pearson Education Asia, Delhi, 2002
3. C.L. Liu, Elements of Discrete Mathematics, The Mc Graw-Hill, India 1985.
4. Bernard Kolman, Robert C. Busby, Sharan Cutler Ross, Discrete Mathematical Structure, 4th Edition, Pearson Education Pvt. Ltd., New Delhi 2003

Semester-IV

MAJOR-5 MATH: 2210: INTRODUCTION TO REAL ANALYSIS – II
(4 CREDITS)

Course Objectives:

1. To introduce the concept of limit and continuity of functions
2. To introduce the notion of differentiability and some fundamental results on differentiation.

	Course Outcome
CO 1	To learn some applications of differentiability of functions
CO 2	To introduce the Riemann theory of integration and the fundamental theorem of calculus
CO 3	To learn about pointwise and uniform convergences of sequence of functions

Unit I: (Sections 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6 of [1])
Continuous functions– Algebra of continuous functions – ε-δ definition of continuity – Intermediate value theorem– Extreme value theorem– Monotonic function– Limit of a function – Limit at infinity.

Unit II: (Sections 4.1 and 4.2 of [1])
Differentiability of functions – Chain rule – Roll's theorem – Mean value theorems –Applications of mean value theorem – Inverse function theorem – Cauchy's form of mean value theorem.

Unit III: (Sections 4.3, 4.4, 4.5 and 4.6 of [1])
L'Hospital's rule–Darboux theorem – Taylor's theorem – Convex functions – Derivative test for convexity.

Unit IV: (Sections 6.1, 6.2, 6.3 and 6.4 of [1])
Riemann integration – Upper and lower sums –Properties of Riemann integration – Basic estimates for integrals – Fundamental theorem of calculus (I & II), Mean value Theorem for Integrals.

Unit V: (Sections 7.5 and 7.10 of [2])
Improper integrals (First and second kind) – Absolute Convergence – conditional convergence – integral test – Cauchy principal value.

Text book:

1. Ajith Kumar and S.Kumaresan, *A Basic Course in Real Analysis*, CRC Press (2014).
2. Richard R Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt Ltd, New Delhi, Indian Edition 1970.

Reference Books

1. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, Third Edition, Wiley India edition, 2000.
2. Kenneth A. Ross, *Elementary Analysis: The Theory of Calculus*, springer, 2e (2013).

MAJOR-6 **MATH: 2220: GROUP THEORY** **(4 CREDITS)**

Course Objectives:

1. To introduce the concept of Group and Homomorphisms.
2. To introduce the notion of special subgroups and Symmetric group.

	Course Outcome
CO 1	To learn some special sub groups like Normal subgroups.
CO 2	To introduce the Coset concepts and Lagrange's Theorem.
CO 3	To learn about Automorphisms.

Unit I

Introduction to Groups - Definition and Examples of Groups – Elementary Properties of Groups – Subgroups - Subgroup Tests - Examples of Subgroups.

Unit II

Cyclic Groups - Properties of Cyclic Groups - Classification of Subgroups of Cyclic Groups - Permutation Groups - Cycle Notation - Properties of Permutations.

Unit III

Isomorphisms - Cayley's Theorem - Properties of Isomorphisms – Automorphisms.

Unit IV

Properties of Cosets - Lagrange's Theorem and Consequences, Normal Subgroups - Factor Groups - Applications of Factor Groups.

Unit V

Group Homomorphisms - Properties of Homomorphisms - The First Isomorphism Theorem.

Text Book:

Joseph A. Gallian, Contemporary Abstract Algebra, 8th Edition, Cengage Learning India Private Limited. **Chapters 2,3,4,5,6,7,9(except Internal Direct Products) and 10.**

Reference books

1 M. Artin: Algebra, Prentice-Hall of India, 1991.

2. I.N.Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

MAJOR-7 MATH: 2230 ELEMENTS OF DIFFERENTIAL EQUATIONS

(4 CREDITS)

Course Objectives:

1. To understand ordinary and first order partial differential equations and their applications
2. To enable students to understand solving the first and second order ODES and first order PDEs.

	Course Outcome
CO 1	To solve a system of first order ODEs
CO 2	To analyze the stability of a Dynamical System using Differential Equations and their solutions
CO 3	To Solve First Order Partial Differential Equations

Unit I:

Exact differential equations- Integrating factors – Linear differential equations- Bernoulli equation – Modeling: Electric circuits – Orthogonal trajectories of curves.

Unit II:

Homogeneous linear equations of second order – Second order homogeneous equations with constant coefficients – Case of complex roots- Complex exponential function – Differential operators – Modeling: Free oscillations – Euler-Cauchy equation – Existence and uniqueness theory – Wronskian.

Unit III:

Non homogeneous equations – Solution by undetermined coefficients – Solution by variation of parameters – Modeling of electric circuits – Higher order linear differential equations – Higher order homogeneous equations with constant coefficients.

Unit IV:

Introduction: vectors, matrices, eigenvalues – Introductory examples – Basic concepts and theory – Homogeneous systems with constant coefficients, phase plane, critical points – Criteria for critical points, Stability.

Unit V:

Non-linear first order PDEs : Compatible systems- Solutions of Quasi linear equations
Charpit's method- Special Types of Charpits Method, -Integral surfaces through a given curve-The Cauchy problem for Quasi Linear case and nonlinear first order PDEs

Text Book

Erwin Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, 1999.
Unit-I: Sections 1.5-1.8; Unit-II: Sections 2.1-2.7; Unit-III: Sections 2.8-2.10, 2.13, 2.14;
Unit-IV: Sections 3.0-3.4;
K. Shankara Rao, Introduction to Partial Differential Equations, PHI Publications,
3rd Edition. 2011. – Chapter 1

Reference Books

1. George F. Simmons, Differential Equations, Tata McGraw-Hill, New Delhi, 1972.
2. Boyce and Di Prima, Differential Equations and Boundary Value Problems, Wiley,10th edition 2012.
3. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall of India Private Ltd, 1991.

Semester-V

MAJOR-8 **MATH: 3110: TOPOLOGY OF METRIC SPACES**

(4 CREDITS)

Course Objectives:

1. To study about some important inequalities and to introduce the notion of metric spaces
2. To study the Baire's category theorem, connected sets and homeomorphisms

	Course Outcome
CO 1	To learn complete metric spaces and to discuss some of the important results regarding completeness
CO 2	To introduce the notion of compactness and its properties
CO 3	To study about the improper integrals and varies tests of convergence for improper integrals

Unit I: (Section 3.10, 4.2, 4.3,5.3, 5.4, 5.5**)**

Metric Spaces – Definition – Examples – Holder inequality – Minkowski's inequality – Convergent sequence – Cauchy sequence – Equivalent metric spaces – Continuous functions on a Metric space – Open sets – Closed sets – Limit points.

Unit II: (Section 5.6, 6.1,6.2)

Oscillation of a function – $F_\sigma$set, $G_\delta$set – Dense and nowhere dense subsets –Baire's category Theorem – Subspaces – Connected sets – Connected subsets of R – Continuity and connectedness.

Unit III: (Section 6.3, 6.4)

Bounded sets – Totally bounded sets – Complete metric spaces – Cantor intersection theorem – Contraction mapping – Contraction mapping theorem.

Unit IV: (Section 6.5, 6.6, 6.7,6.8)

Compactness – Sequential compactness – Heine-Borel property – Finite intersection property- Continuity and compactness – Continuity of inverse functions – Uniform continuity.

Unit V: (Section 9.1, 9.2, 9.4)

Sequences and series of functions – The metric space C[a,b] – pointwise Convergence – Uniform Convergence – Cauchy's criterion for uniform convergence.

Text Book

R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd., 1970.

Reference Books

1. Ajith Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, CRC Press (2014).
2. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, Third Edition, Wiley India edition 2000.
3. S. Kumaresan, Topology of Metric spaces, Second Edition, Narosa Publishing House, 2005.
4. Pawan K. Jain and Khalil Ahmad, Metric Spaces, (Second Edition), Narosa Publishing House 2004.

MAJOR-9 **MATH:3120: RING TEORY** **(4 CREDITS)**

Course Objectives:

1. To introduce the concept of Rings and Homomorphisms of Rings.
2. To introduce the notion of special subrings and Integral Domains.

	Course Outcome
CO 1	To learn some special Integral Domain like ED, PID and UFD.
CO 2	To introduce the Quotient ring concepts and Fundamental Theorem.
CO 3	To learn about Fields.

Unit I

Introduction to Rings - Motivation and Definition of Rings – Examples of Rings – Properties of Rings – Subrings - Definition and Examples of Integral Domains – Fields - Characteristic of a Ring.

Unit II

Ideals - Factor Rings - Prime Ideals and Maximal Ideals - Definition and Examples of Ring Homomorphisms - Properties of Ring Homomorphisms - The Field of Quotients.

Unit III

Polynomial Rings - The Division Algorithm and Consequences - Principal ideal domain - Factorization of Polynomials - Reducibility Tests - Eisenstein's Criterion- Irreducibility Tests.

Unit IV

Unique Factorization in $Z[x]$ - Divisibility in Integral Domains – Irreducibles and Primes - PID Implies Irreducible Equals Prime.

Unit V

Unique Factorization Domains – PID Implies UFD – $F[x]$ Is a UFD – Euclidean Domains –ED Implies PID – ED Implies UFD.

Text Book:

Joseph A. Gallian, Contemporary Abstract Algebra, 8th Edition, Cengage Learning India Private Limited.

Chapter 12 to Chapter 18.

Reference books

1 M. Artin: Algebra, Prentice-Hall of India, 1991.
2. I.N.Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.
3. David S. Dummit and Richard M. Foote, Abstract Algebra (Third Edition), John Wiley and sons, 2004

MAJOR-10 MATH: 3130: MULTIVARIABLE CALCULUS (4 CREDITS)

Course Objectives:

1. To learn about differentiation, partial differentiation and to calculate directional derivatives and gradients.
2. To learn about maxima and minima of two and more variables

	Course Outcome
CO 1	To apply the double and triple integrals to find volume and area.
CO 2	To apply line and surface integrals for computing over curves and surface
CO 3	To learn about integral theorems in vector calculus

Unit I: Differentiation (Sections 2.1, 2.2, 2.3, 2.4,2.5**)**
Graphs and level curves – Limits and continuity – Partial derivatives – Differentiability – The chain rule – Gradients and directional derivatives.

Unit II: Higher Order Derivatives (Sections 3.1, 3.2, 3.3, 3.4, 3.5)
Higher order partial derivatives – Taylor's theorem – Maxima and minima – Second derivative test – Constrained extrema and Lagrange multipliers.

Unit III: Multiple Integral (Sections 5.2, 5.3, 5.4, 5.5)
Double integrals – Triple integrals – Change of variables – Cylindrical and Spherical coordinates.

Unit IV: Integrals over curves and surfaces (Sections 6.1, 6.2, 6.3, 6.4)
Line integrals – Parametrized surfaces – Area of a surface – Surface integral.

Unit V: The Integral Theorems of Vector Analysis (Sections 7.1, 7.2, 7.3)
Green's theorem – Stokes's theorem - Gauss divergence theorem.

Text Book

J.E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer- Verlag, 2009.

Reference Books

1. George B.Thomas, Jr. and Ross L. Finney, Calculus, 9th Edition, Pearson Education, 2006.
2. Richard Courant and Fritz John , Introduction to Calculus and Analysis, Volumes I & II, Springer, SIE, 2004

MAJOR-11 INTERNSHIP / COMPREHENSIVE EXAM WITH VIVO VOCE
(4 CREDITS)

(Two Months in Industries / Universities / Research Institutes etc.)

Objective: The internship program for mathematics graduates aims to provide real-world experience, enhance mathematical skills, and offer opportunities to apply mathematical knowledge in various professional settings. The curriculum may enable mathematics undergraduates to work on practical projects.

Month 1: Foundation and Skill Development

Week 1-2: Orientation and Introduction to the Organization - Understanding the internship structure - Introduction to the team and projects - Introduction to specific mathematical problems in recent advancements of Mathematics

Week 3-4: Learning Basics in Program Specific Subject (e.g. Linear Algebra and Optimization, Differential Equations, Topology, Functional Analysis, Advanced Agebra, Graph Theory etc.)

Week 5-6: Mathematical Projects - Collaborate on real projects within the organization
- Apply mathematical concepts to solve problems - - Present project progress and results

Week 7-8: Final Project and Presentation - Work on an individual or group project
- Develop a presentation to showcase the project results - Presentation to the project supervisor.

Note: Students unable to arrange the above can make a project based on the first 2 years papers under the guidance of the Department faculties and should go through a comprehensive Exams and vivo under the approval of the Program Committee Meetings.

Evaluation Process:

1. Performance Assessment: Regular feedback from mentors on the intern's progress.
- Evaluation of assignments, projects, and tasks - Interns should have a mid-term review with their mentors to discuss their progress/improvement.

2. Final Evaluation: Evaluation of the final project, presentation, and report.
- Assessment of learning skills (with viva-voce).

3. Certificate of Completion: Successful interns may receive a certificate of completion, detailing their achievements and skills acquired during the internship.

Semester-VI

MAJOR-12 MATH: 3210: FUNDAMENTALS OF COMPLEX ANALYSIS

(4 CREDITS)

Course Objectives:

1. To learn about complex numbers and to analyze limit, continuity and differentiation of functions of complex variables.
2. To learn about analytic functions and construction of analytic functions.

	Course Outcome
CO 1	To understand Cauchy theorem and Cauchy integral formulas and apply these to evaluate complex contour integrals
CO 2	To represent analytic functions as Taylor and Laurent series
CO 3	To learn and classify singularities, poles and residues and evaluate complex integrals using the residue theorem

Unit I: (Sections 1 to 23)

Complex conjugates - Exponential form – Products and powers in Exponential form- Arguments of Products and Quotients- Roots of Complex numbers- Regions in the Complex plane- Functions of a complex variable- Mappings- Mappings by the exponential function- Limits- Theorems on Limits- Limits involving point at infinity- Continuity- Derivatives, Differentiation Formulas, Cauchy-Riemann Equations, Sufficient conditions for Differentiability- Polar Coordinates.

Unit II: (Sections 24 to 36)

Analytic functions, Examples, Harmonic functions, uniquely determined Analytic functions, The Exponential functions, The Logarithmic Function, Branches and derivatives of Logarithms, Some Identities involving Logarithm, Complex Exponents, Trigonometric Functions, and Hyperbolic Functions.

Unit III: (Sections 37 to 54)

Derivatives of functions w(t), Definite Integrals, Some Examples, Upper bounds for Moduli, Anti derivatives, Cauchy-Goursat Theorem (Statement only) , Multiply Connected Domains, Cauchy Integral Formula, An extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorm and The Fundamental Theorem of Algebra, Maximum Modulus Principle.

Unit IV: (Sections 55 to 62)

Taylor's Series, Proof of Taylor's Theorem, Examples, Laurent Series, Proof of Laurent's Theorem, Examples.

Unit V: (Sections 68 to 77)

Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points, Residues at Poles, Examples, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points.

Text Book:

James Ward Brown and Ruel V. Churchill. Complex Variables and Applications,. Tata McGraw - Hill Education. 8th Edition, 2009.

Reference Books:

1. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons, 9th Edition, 2011
2. H.A. Priestley, Introduction to Complex Analysis, Second Edition, Oxford University Press, 2003
3. John B. Conway, Functions of One Complex Variable, Springer, ISE, 1973
4. Serge Lang, Complex Analysis, Springer Publishing Company, 4th Edition, 2009.
5. S. Ponnusamy, Foundations of Complex analysis, (2nd Edition), Narosa, 2011.
6. V. Karunakaran, Complex Analysis, (2nd Edition), Narosa 2005.

MAJOR-13 MATH: 3120: INTRODUCTION TO LINEAR ALGEBRA
(4 CREDITS)

Course Objectives:

1. To understand vector spaces by its definition and examples.
2. To know how to represent a linear transformation by a matrix

	Course Outcome
CO 1	To learn elementary operations on Matrices and how to apply them to find the solutions of a system of equations
CO 2	To learn the properties of determinant of matrices
CO 3	To know about inner products and orthogonalization

Unit I: Section 1.2 to 1.6
Abstract Algebra Concepts – Groups- Subgroups- Fields- examples Vector space- Subspace-linear combinations and systems of linear equations- Linear dependence and linear independence- Basis and dimension.

Unit II: Section 2.1 to 2.5
Linear Transformations- Null spaces- Range spaces- Dimension theorem- Matrix representation of linear transformation- composition of linear transformations and Matrix multiplication- Invert ability and Isomorphism- The change of coordinate matrix.

Unit III: Section 3.1 to 3.4
Elementary matrix Operations and elementary matrices- The rank of a matrix and matrix inverses- systems of linear equations- Theory and computation

Unit IV: Section 4.1 to 4.4 and 5.1 to 5.2, 5.4
Determinants of order 2 and order n- propertie4s of determinants- Important facts about determinants- Eigen values and Eigen vectors- Diagonalizability- Invariant spaces and Cayley- Hamilton theorem.

Unit V: Section 6.1, 6.2
Inner products and norms- The Gram-Schmidt orthogonalisation process and orthogonal complements.

Text Book

Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, Linear Algebra, 4th Edition,
Printice Hall of India Pvt. Ltd., 2006

Reference Books

1. S. Kumaresan, Linear Algebra Geometric Approach, Prentice Hall of India Pvt. Ltd., 2000.
2. I. N. Herstein, Topics in Algebra, 2nd Edition, John Wiley & Sons, 2003.
3. David C. Lay, Linear Algebra and Applications (2nd Edition), Addison Wesley, 1997.
4. John B. Fraleigh, A First Course in Abstract algebra, (7th Edition), Pearson 2013.

MAJOR-14 MATH: 3230: GRAPH THEORY (4 CREDITS)

Course Objectives:

1. To introduce the notion of graphs and the basic terminologies in graphs
2. To learn the concept of spanning trees, Cayley's formula and to introduce the concept of connectivity and edge connectivity of graphs

	Course Outcome
CO 1	To study about independent sets and matching and some of their properties
CO 2	To introduce the idea of Eularian and Hamiltonian graphs and their applications
CO 3	To study vertex coloring and edge coloring of graphs and some of the famous theorem in coloring problems

Unit I: (Sections 1.1-1.6, 4.1-4.3)
Graphs – Subgraphs – Isomorphism of graphs – Degrees of Vertices – Paths and Connectedness – Automorphism of a Simple Graph – Trees – Centers and Centroid.

Unit II: (Sections 3.1-3.3, 4.4,4.5)
Counting the Number of Spanning Trees – Cayley's Formula– Vertex Cuts and Edge Cuts – Connectivity and Edge-connectivity.

Unit III: (Sections 5.1-5.5)
Vertex Independent sets and Vertex Coverings – Edge-Independent Sets – Matchings and Factors –M-Augmenting Paths – Matchings in Bipartite Graphs – Halls Theorem on Bipartite graphs – Tutte's 1-Factor Theorem (without proof).

Unit IV: (Sections 6.1-6.3)
Eulerian graphs – Necessary and sufficient condition for Eulerian graphs – Hamiltonian graphs – Dirac theorem – Closure of a graph.

Unit V: (Sections 7.1,7.2,7.3.1, 7.6.2, 8.1-8.3)
Vertex Coloring – Chromatic Number –Critical Graphs – Brooks' Theorem – Edge Colorings of Graphs – Vizing's Theorem (without proof) – Planar and Nonplanar Graphs – Euler's Formula and its Consequences.

Text Book:-

1. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory (Universitext), Second Edition, Springer New York 2012.

Reference Books:-

1. Bondy, J.A and Murthy, U.S.R, Graph Theory with Applications, Macmillan Press Ltd, New Delhi – (1976).Douglas B. West, Introduction to Graph Theory, Second Edition, PHI Learning Private Ltd, New Delhi-2011.
2. G. Chartrand, Linda Lesniak and Ping Zhang, Graphs and Digraphs, Fifth Edition, CRC press 2011.

MAJOR-15 MATH -3240 LINEAR PROGRAMMING (4 CREDITS)

Course Objectives:

1 To learn the concept of LPP and Simplex Method
2 To learn the concept of Transportation and Assignment Model

	Course Outcome
CO 1	To study about Modeling with LPP and Simplex Method
CO 2	To study about Transportation Problem
CO 3	To study about Assignment problem and Duality

Unit – I: Modeling with Linear Programming (Chapter-2, Sections 2.1, 2.2, 2.4)

Two-Variable Linear Programming Model, Graphical LP Solution–Solution of a Maximization Model, Solution of a Minimization Model. Linear Programming Applications –Investment, Production Planning and Inventory Control, work force planning, Urban Planning,

Unit – II: The Simplex Method-I (Chapter-3, Sections 3.1, 3.2, 3.3)

LP model in Equation Form – Converting Inequalities into Equations with Nonnegative Righthand side, Dealing with Unrestricted variables. Transition from Graphical to Algebraic Solution, Iterative Nature of Simplex method, Computational Details of Simplex Method.

Unit – III: The Simplex Method-II (Chapter-3, Sections 3.4, 3.5,)

Artificial Starting Solution– Big-M-Method, Two-Phase Method. Special Cases – Degeneracy, Alternative Optima, Unbounded Solution, Infeasible Solution.

Unit – IV: Transportation Model (Chapter-5, Sections 5.1, 5.2, 5.3)

Definition of the Transportation Model, Nontraditional Transportation Models, The Transportation Algorithm, Determination of the Starting Solution, Iterative Computations of the Transportation Algorithm, Simplex Method Explanation of the Method of Multiplier.

Unit – V: Assignment Model and Duality (Chapter-5, Sections 5.4 & Chapter-7, Sections 7.4)

The Assignment Model, The Hungarian Method, Simplex Explanation of the Hungarian Method. Duality – Matrix Definition of the Dual Problem, Optimal Dual Problem.

Text Book:

1. Hamdy A Taha – Operations Research: An Introduction, 10th Edition, Pearson Prentice Hall, 2017.

Reference Books:

1. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research* (9th Edition), Tata McGraw Hill, Singapore, 2009.
2. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.

Semester-VII

MAJOR-16 **MATH 4110: ADVANCED ALGEBRA**

(4 CREDITS)

Course Objectives:

1. To learn isomorphism theorems group actions
2. To study about class equations and sylow theorems and its applications

	Course Outcome
CO 3	To know the direct product of groups and classifications of groups by applying the fundamental theorem finitely generated Groups
CO 4	To know the properties of Euclidean domain, Principal ideal domain and Unique factorization domain.
CO 5	To study the properties of Polynomial rings.

Unit I:

The isomorphism theorems -Composition Series - Transpositions and Alternating groups,

Unit II:

Group Actions: Group Actions and Permutation representations-Group acting on themselves by left multiplication-Cayley's theorem

Unit III:

Group acting on themselves by conjugation -The class equation- Automorphisms-The Sylow theorems- The simplicity of A_n.

Unit VI:

Direct and semi-direct products and abelian groups: Direct products- The fundamental theorem of finitely generated abelian groups.

Unit V:

Polynomial rings: Definitions and basic properties- Polynomial rings over fields- Polynomial rings that are unique factorization domains -Irreducible criteria.

Text Book:

David S. Dummit and Richard M. Foote, Abstract Algebra (Third Edition), John Wiley and sons, 2004.

Chapter 3 - Sections 3.3 to 3.5

Chapter 4 - Sections 4.1 to 4.6

Chapter 5 - Sections 5.1 and 5.2

Chapter 9 - Sections 9.1 to 9.4

Reference books

1 M. Artin: Algebra, Prentice-Hall of India, 1991.

2. I. N. Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

3. N. Jacobson: Basic Algebra, Volumes I & II, W. H. Freeman, 1980.

4. S. Lang: Algebra, 3rd edition, Addison-Wesley, 1993.

MAJOR-17 MATH: 4120 TOPOLOGY (4 CREDITS)

Course Objectives:

1. To introduce the notion of metric spaces and to characterize open sets in the real line
2. To study the concept of topological spaces and to study their properties like second count ability and separability

	Course Outcome
CO 1	To discuss in details about compactness of topological spaces and to prove the Tychnoff's theorem with some applications
CO 2	To study bout the equivalent versions of compactness in metric spaces
CO 3	To discuss some important theorems like Urysohn's lemma and the Tietze extension theorem. Also, we study about connected spaces

Unit I: (Revision of Sections 1-3, Section 4-8, 9-12)
Revision of sets - Functions - Product of sets – Relations – Countable sets – Uncountable sets – Partially ordered sets and lattices – Metric spaces – Definition and examples – Open sets and closed sets in metric spaces – Open subsets of real line.

Unit II: (Sections 16, 17 and 18)
Topological spaces -- Definitions and examples - Closure and related concepts – Open bases and open sub bases – Separability and second count ability -Lindloff's Theorem

Unit III: (Sections 21 – 23)
Compactness – Basic results -- Continuous maps on compact sets - Characterization of compactness by basic and sub basic open covers – Tychon off's theorem - Generalized heine – Bore theorem.

Unit IV: (Sections 24,26)
Compactness for metric spaces – Sequential compactness - Lebesgue covering lemma - Sequential compactness and compactness coincide on metric spaces - T_1spaces - Hausdorff spaces.

Unit V: (Sections 27,28,31,32)
Completely regular spaces and normal spaces – Urysohn's lemma and Tietze extension theorem- –Connected spaces – Components of a space.

Text Book

G.F.Simmons, an Introduction to Topology and Modern Analysis, McGraw-Hill Kogakusha, Tokyo, 1963

Reference Books

1. J. R. Munkres, Toplogy, Pearson Education Inc., Second Edition, 2000.
2. Stephen Willard, General Topology, Dover Publication 2004.
3. J. Dugundgi, Toplogy, Allyn and Bacon, Boston, 1966.
4. Fred.H. Croom, Principles of Topology, Dover publications, 2016.

MAJOR-18 (4 CREDITS)

MATH: 4130: DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS

Course Objectives:

1. To study the qualities properties of ordinary differential equations.
2. To study the hypergeometric functions, Bessel functions and Legendre polynomials which arising as solution of ODEs

	Course Outcome
CO 1	To study the series solutions of ODEs,
CO 2	To study the existence and uniqueness of solutions of first order ODEs.

Unit I: [Chapter-4, Sections: 25, Chapter-5, Sections: 26, 27, 28, 29, 30 & Chapter -7, Sections: 40 of [1]]

Qualitative properties of solutions – The Sturm Separation Theorem, The Sturm comparison theorem– Eigen values and Eigen functions and vibrating string. Series solutions of first order equations – Second order linear equations – Ordinary points - Regular singular points

Unit II: [Chapter-5, Sections: 31 of [1] & Chapters: 4 & 7 of [2]]

Gauss Hypergeometric equations. Gauss's hypergeometric and Confluent hypergeometric functions, integral representations, differentiation formulas, transformation formulas, summations formulas.

Unit III: [Chapter-8, Sections: 44, 45, 46 47 of [1]]

Legendre polynomials – Properties of Legendre polynomials – Bessel functions- The Gamma function - Properties of Bessel Function.

Unit IV: [Chapter-10, Sections: 55, 56 of [1]]

Linear systems – Homogeneous linear system with constant coefficients.

Unit V: [Chapter-13, Sections: 68, 69 of [1]]

The existence and uniqueness of solutions – The method of successive approximations – Picards's theorem.

Text Book

1) G. F. Simmons, Differential Equations with Applications and Historical Notes, 2nd Edition, McGraw Hill Education(India) Company, 2003.

Sections: 22-30, 32-35, 37-38 and 55-56.

2) E. D. Rainville, Special *functions*, Macmillan, New York, 1960.

References

1. Earl Coddington and Norman Levinson, Theory of ordinary Differential equations, TATA McGraw Hill, 2017.
2. N. M. Temme, *Special functions: An introduction to the classical functions of mathematical physics*, John Wiley& Sons, New York, 1996.

Semester-VIII

MAJOR-19 MATH: 4210: ADVANCED REAL ANALYSIS (4 CREDITS)

Course Objectives:

1. To study about functions of bounded variation, double sequence, double series and infinite products
2. To study about convergence of sequences and series of functions and their properties

	Course Outcome
CO 1	To prove some famous theorems like Weierstrass approximation theorem and stone Weierstrass theorem
CO 2	To study about differentiability of functions of several variables and to prove the contraction mapping theorem.
CO 3	To prove the important theorems- The inverse function and the implicit function theorem

Unit I:(Chapter:6 and Sections: 8.20 to 8.23, 8.26 and8.27 of [2])

Functions of bounded variation - Double sequences - Double series - Rearrangement theorem for double series- A sufficient condition for the equality of iterated series.

Unit II: (Chapter: 7 of [1], Subsections 7.1 to 7.25)

Sequence and Series of functions - Examples - Uniform convergence and Continuity - Uniform convergence and Integration - Uniform convergence and Differentiation - Double sequences and series - Iterated limits- Equicontinuous Families of Functions - Arzela – Ascoli Theorem

Unit III:(Chapter: 7 of [1] subsections: 7.26 to7.33 and chapter 8 of [1])

The Weierstrauss theorem for algebraic polynomials- The Stone - Weierstrauss Theorem - Power Series - The Exponential and Logarithmic Functions - The Trigonometric Functions - Fourier Series - The Weierstrauss theorem for the Trigonometric polynomials.

Unit IV: (Chapter:9 of [1], Subsections: 9.6 to 9.23)

Functions of Several Variables - Linear Transformation - Differentiation - The Contraction Principle.

Unit V:(Chapter: 9 of [1], Subsections:9.24 to 9.38)

The inverse function Theorem - The implicit Function Theorem - The Rank Theorem – Determinants.

Text Books

1. Walter Rudin, Principles of Mathematical Analysis- McGraw Hill International Editions, Mathematics series, 1976.
2. Apostol, Mathematical Analysis, Narosa Publishing House, Indian edition,2002.

Reference Books

1. Patrick M. Fitzpatrick Advanced Calculus, Amer. MATH. Soc. Pine and Applied Undergraduate Texts, Indian Edition, 2009.
2. Kenneth A. Ross, Elementary Analysis, The Theory of Calculus, Springer-Verlag,1980.
3. N.L.Carothers, *Real Analysis*, Cambridge University Press(2000)
4. G.F.Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 2017.

MAJOR-20 MATH 4220: ADVANCED LINEAR ALGEBRA

(4 CREDITS)

Course Objectives:

1. To understand linear transformations Characteristic roots- Similarity of linear transformations, Invariant subspaces and matrices.
2. To understand triangular forms- Nilpotent transformations.

	Course Outcome
CO 1	To understand Jordan forms- Fundamental theorem on modules over PID.
CO 2	To understand Rational canonical form- Trace- Transpose & Determinants.
CO 3	To understand Hermitian - Unitary and Normal transformations - Real quadratic forms.

Unit I: Sections – 6.1,6.2, 6.3 [1] and 13.1-13.2 [2]
Field theory: Splitting fields and Algebraic closures. The Algebra of linear transformations-Characteristic roots- Similarity of linear transformations.

Unit II: Sections – 6.4 and 6.5 [1]
Invariant subspaces and matrices. Reduction to triangular forms.

Unit III: Sections – 6.6 and 4.5 [1]
Nilpotent transformations - Index of nil potency and invariant of nilpotent transformation. Jordan blocks and Jordan forms-

Unit IV: Sections - 6.7, 6.8 and 6.9 [1]
Modules - Cyclic modules - Fundamental theorem on modules over PID- Rational canonical form- Trace- Transpose and Determinants.

Unit V: Sections – 6.10 and 6.11 [1]
Hermitian - Unitary and Normal transformations - Real quadratic forms.

Text Book: 1. I.N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.
2. Abstract Algebra (Third Edition) by David S. Dummit and Richard M. Foote,
(Sections 13.1-13.2)

Reference Books

1. M. Artin, Algebra, Prentice-Hall of India, 1991
2. N. Jacobson, Basic Algebra, Volumes I & II, W. H. Freeman, 1980.
3. S. Lang, Algebra, 3rd edition, Addison-Wesley, 1993
4. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra (2nd Edition)Cambridge University Press, Indian edition, 1997
5. Kenneth Hoffmann and Ray Kunze, Linear Algebra, (Second edition), Pearson, 2015
6. S. Friedberg, A. Insel and L. Spence, Linear Algebra, (4^{th} Edition) Pearson, 2015.

Minor-9 : MATH 4211 : COMPLEX ANALYSIS (4 CREDITS)

Course Objectives:

1. To Learn and understand about the properties of Line integral and Zeros and Poles.
2. To discuss about the theorems on Series expansion, Residue and Factorization.

	Course Outcome
CO 1	To discuss about the Line integrals, Cauchy theorem and Cauchy integral formula
CO 2	To study about the Zeros and Poles of functions and the Maximum principle
CO 3	To study about the Calculus of Residues, Evaluation of Definite Integrals and Harmonic functions
CO 4	To study about Series Expansions and Partial Fractions and Factorization
CO 5	To study the Jenson Formula-Hadamard' Theorem and the Riemann Zeta Function

Unit I: [Chapter-4, Sections: 1 and 2]

A quick review of analytic function – Cauchy-Riemann equations. Line integrals-Cauchy's theorem for a Rectangle-Cauchy's theorem in a Disc-Cauchy's integral formula-Higher derivatives

Unit II: [Chapter-4, Sections: 3 and 4].

Local properties of Analytical Functions-Removable Singularities, Zeros and poles-The Maximum principle- The general form of Cauchy's theorem.

Unit III: [Chapter-4, Sections:5 and 6].

The Calculus of Residues-The Residue Theorem- The Argument principle-Evaluation of Definite Integrals. Harmonic functions- Poisson's formula- Schwarz's theorem- The Reflection Principle.

Unit IV: [Chapter-5, Sections: 1 and 2].

Power Series Expansions-Weierstrass's Theorem-The Taylor series-The Laurent's series. Partial Fractions and Factorization-Infinite Product-The Gamma function-Stirling formula.

Unit V: [Chapter-5, Sections: 3 and 4, Chapter-8, Sections: 1]

Entire Functions-Jenson Formula-Hadamard' Theorem. The Riemann Zeta Function-Extension of Riemann Zeta function to the Whole Plane-The Functional Equation-The Zeros of the Zeta Function. Analytic Continuation.

Text Book: L.V. Ahlfors, Complex analysis, Third Edition, McGraw Hill Book Company,1979.

References:

1. John. B. Conway, Functions of one Complex Variable, Second Edition, Narosa Publishing House, 2002.
2. B. C. Palka, An Introduction to the Complex function Theory, Springer, 1991.
3. H.A. Priestley, Introduction to Complex Analysis, Second Edition, Oxford University Press, 2003.
4. S. Ponnusamy, Foundations of Complex analysis, (2nd Edition), Narosa, 2011
5. Donald Sarason, Notes on Complex Function Theory, Hindustan Book agency, 1994.

Minor-10 : **MATH 4221: MEASURE AND INTEGRATION**
(4 CREDITS)

Course Objectives:

1. Motivation to Lebesgue measure theory and the introduction of Lebesgue outer measure
2. To study about Lebesgue measurable sets and their properties.

	Course Outcome
CO 1	To introduce Lebesgue measurable functions and to prove important theorems like Egoroff's theorem and Lusin's theorem
CO 2	To study about the Lebesgue integrable functions and to prove some important convergence theorems
CO 3	To study about absolutely continuous functions and to prove the fundamental theorem of calculus for Lebesgue integral

Unit I: (Sections: 3.1, 3.2, 3.3, 3.6 of [1] and 2.1, 2.2 of [2])

Motivation to Lebesgue Measure Theory – General extension Theory – Algebra of sets – Examples – Finitely/Countably additive set functions – Ulam's Theorem – Continuity from below/above of measures – The Lebesgue outer measure m^* - Examples – Properties.

Unit II: (Sections: 2.3, 2.4, 2.5, 2.6, 2.7 of [2])

Lebesgue measurable sets – Examples – The set of all Lebesgue measurable sets M is an algebra - $m^*$is finitely additive over M – M is a sigma algebra – m^* is a measure on M – Outer and inner approximation of Lebesgue measurable sets by open and closed sets respectively –Continuity of the Lebesgue measure – Example of a nonmeasurable set – The Cantor Lebesgue function.

Unit III: (Sections: 3.1, 3.2, 3.3 of [2])

Lebesgue measurable functions – Examples – Pointwise limit of sequence of measurable functions – Simple functions – The simple approximation Lemma – The simple approximation Theorem – Egoroff's Theorem – Lusin's Theorem.

Unit IV: (Sections: 4.2, 4.3, 4.4, 4.5,5.3 of [2])

The Lebesgue integral of a simple function – The Lebesgue integral of a bounded measurable function over a set of finite measure – Properties – The Bounded Convergence Theorem - The Lebesgue integral of a nonnegative measurable function – Properties – Chebychev's inequality – Fatou's Lemma – Monotony Convergence Theorem – The general Lebesgue integral – The Lebesgue dominated Convergence Theorem – Characterization of Riemann integrable functions – Improper Riemann integrals and their Lebesgue integrals.

Unit V: (Sections: 6.1, 6.2, 6.3(upto6.3.6) of [1])

Review of functions of bounded variation –Absolutely continuous functions – Lebesgue's Theorem on differentiability of monotony functions – The Lebesgue singular function – Fundamental Theorem of Calculus [I and II] for the Lebesgue integral

Text Books:

1. Inder K. Rana, *An Introduction to Measure Theory and Integration ,(2e)*, Narosa (2007)
2. H. L. Roylan, P. M. Fitzpatrick, *Real Analysis –Fourth Edition*, Prentice Hall of India (2013).

Reference books:

1. De Barra.G, *Measure Theory and Integration*, 2e, New Age International Publishers (2013).
2. Howard J.Wilcox, *An Introduction to Lebesgue Integration and Fourier Series*, Dover (1995).
3. Paul R. Halmos, *Measure Theory*, Springer (1976).
4. N.L.Carothers, *Real Analysis*, Cambridge University Press(2000).
5. C.D. Aliprantis and O.Burkinshaw, *Principles of Real Analysis*,3e, Academic Press (Elsevier).

LIST OF MINORS FOR 4th Year (ANNEXURE - I)

Minor: **MATH 4111: CRYPTOGRAPHY** **(4 CREDITS)**

Course Objectives:

1. To know various kinds of classical cryptography
2. To know about data encryption standards

	Course Outcome
CO 1	To know about public key crypto system
CO 2	To learn various methods of digital signatures
CO 3	To learn about hashing and its applications

Unit I:
Introduction: Overview of course- Classical cryptography [parts of Chapter 1].

Unit II:
Secret Key Encryption: Perfect Secrecy - One time pads [Chapter 2.1], Stream ciphers and the Data Encryption Standard (DES) [Chapter 3 (excluding 3.6)], The Advanced Encryption Standard (AES) - adopted September 2000.

Unit III:
Public Key Encryption: Factoring and the RSA encryption [Chapter 4.1 -4.4], Discrete log- Diffie-Hellman Key Exchange [Chapter 8.4 (only pages 270-273)].

Unit IV:
ElGamal encryption [Chapter 5 (only pages 162-164)] , Digital Signatures [Chapter 6 (excluding 6.5 - 6.6)], One-time signatures- Rabin and ElGamal signatures schemes- Digital Signature Standard (DSS).

Unit V:
Hashing: Motivation and applications- Cryptographically Secure Hashing. [Chapter 7.1-7.3,7.6], Message Authentication Codes (MAC)- HMAC- Network Security - Secure Socket Layer (SSL)- I Psec.,Secret Sharing- Definition. Shamir's threshold scheme [Chapter 11.1], Visual secret sharing schemes.

Text Book
D. R. Stinson,s Cryptography, Theory and Practice, CRC Press, 1995.

Reference Books

1. Richard A. Mollin, An Introduction to Cryptography, Chapman & Hall / CRC, Boca Raton, 2000.

2. Dominic Walsh, Codes and Cryptography, Oxford Science Publications, Clarendon Press, Oxford, 1988.

Minor: MATH 4121: NUMERICAL ANALYSIS (4 CREDITS)

Course Objectives:
To find the roots using numerical methods.
To apply numerical techniques for solving systems of equations.

	Course Outcome
CO 1	To learn various interpolation techniques.
CO 2	To know numerical integration.
CO 3	Solve initial and boundary value problems in differential equations using numerical methods.

Unit I: Nonlinear Equations in One Variable:
Fixed point iterative method – convergence Criterion -Aitken's Δ2- process - Sturm sequence method to identify the number of real roots – Newton - Raphson's methods convergence criterion Ramanujan's Method - Bairstow's Method.

Unit II: Linear and Nonlinear System of Equations:
Gauss eliminations with pivotal strategy jacobi and Gauss Seidel Itervative Methods with convergence criterion. LU - decomposition methods – (Crout's, Choleky and DeLittle methods) – consistency and ill conditioned system of equations - Tri-diagonal system of equations – Thomas algorithm. Iterative methods for Nonlinear system of equations, Newton raphson, Quasi newton and Over relaxation methods for Nonlinear system of equations.

Unit III: Interpolation:
Lagrange- Hermite- Cubic-spline's (Natural, Not a Knot and Clamped)- with uniqueness and error term, for polynomial interpolation- Bivariate interpolation- Orthogonal polynomials Grams SchmidthOrthogoralization procedure and least square- Chebyshev and Rational function approximation.

Unit IV: Numerical Integration:
Gaussian quadrature, Gauss-Legendre- Gauss-Chebeshev formulas- Gauss Leguree, Gauss Hermite and Spline intergation – Integration over rectangular and general quadrilateral areas and multiple integration with variable limits.

Unit V: Numerical solution of ordinary differential equations:
Initial value problems- Picard's and Taylor series methods – Euler's Method- Higher order Taylor methods - Modified Euler's method - RungeKutta methods of second and fourth order – Multistep method - The Adams - Moulton method - stability - (Convergence and Truncation error for the above methods). Boundary - Value problems – Second order finite difference and cubic spline methods.

Text books

1. M. K. Jain, S. R. K. Iyengar and R.K. Jain, Numerical methods for scientific and Engineering computation, Wiley Eastern Ltd. 1993, Third Edition.
2. C.F. Gerald and P.O. Wheatley, Applied Numerical Methods, Low- priced edition, Pearson Education Asia 2002, Sixth Edition.
3. M.K. Jain, Numerical solution of differential equations, Wiley Eastern (1979), Second Edition.

Reference books

1. S.C. Chapra and P.C. Raymond, Numerical Methods for Engineers, Tata McGraw Hill, New Delhi,2000
2. S.S. Sastry , Introductory methods of Numerical analysis, Prentice - Hall of India, New Delhi, 1998.
3. Kendall E.Atkinson, An Introduction to Numerical Analysis (2nd Edition), Wiley, 2008.

Minor: MATH4131: NUMBERS THEORY (4 CREDITS)

Course Objectives:

1. To study primes
2. To study solution for congruences

	Course Outcome
CO 1	To understand Quadratic residues
CO 2	To study arithmetic functions
CO 3	To study continued fraction and its convergences

Unit II: Section : 1.1-1.3
Divisibility: Introduction -Divisibility- Primes.

Unit II: Section : 2.1-2.11
Solution of congruences – Congruences of higher degree – prime power moduli.

Unit III: Section :3.1-3.3
Quadratic Residues, Quadratic reciprocity law, Jacobi Symbol.

Unit IV: Section :4.1-4.3
Arithmetic functions-Recurrence functions, Mobious Inversion Formula, Irrational numbers, Irrationality of nth root of N, e and pi.

Unit V: Section : 5.6-5.11
Continued fractions and its convergence, representation of an irrational number by an infinite continued fraction. Some special quadratic surds.

Text Book

Treatment as in I. Niven, H.S. Zuckerman and H.L. Montgomery – An Introduction to the Theory of Numbers, New York, John Wiley and Sons, Inc., 2004, 5^{th} Ed.

Books for Reference:

1. **T.M. Apostol –** Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi.
2. **G.H. Hardy and E.M. Wright-** An Introduction to the Theory of Numbers, Oxford University Press, 1979, 5^{th} Ed.

Minor: MATH 4211: CALCULUS OF VARIATIONS (4 CREDITS)

Course Objectives:

1. To learn about functionals and solving related variational problems by Euler's equation
2. To understand and solve the variational problems functionals depending on higher order derivatives

	Course Outcome
CO 1	To study about the general variational of a functional and the Weierstrass Erdmann conditions
CO 2	To study and understand about canonical form of Euler equations and other transformations, Noether's Theorem and conservation laws
CO 3	To learn about second variation and Legendre conditions of a functional

Unit I:

Functionals- some simple variational problems-The variation of a functional- A necessary condition for an extremum-The simplest variational problem-Euler's equation-The case of several variables-A simple variable end point problem-The variational derivative-Invariance of Euler's equation.*[Chapter-1]*

Unit II:

The fixed end point problem for n-unknown functions - Variational problem in parametric form- Functionals depending on higher order derivatives-Variational problems with subsidiary conditions. *[Chapter-2]*

Unit III:

The general variational of a functional- derivation of the basic formula- End points lying on two given curves or surfaces- Broken extremals- The Weierstrass Erdmann conditions. *[Chapter-3]*

Unit IV:

The canonical form of Euler equations- First integrals of the Euler equations- The Legendre transformation- Canonical transformations- Noether's Theorem- The principle of least action- Conservation laws- The Hamilton Jacobi equation-Jacobi theorem.*[Chapter-4]*

Unit V:

The second variation of a functional- The formula for the second variation, Legendre conditions- Sufficient conditions for a weak extremum. *[Chapter-5]*

Text Book:

I.M. Gelfand and S.V.Fomin, *Calculus of Variations,* Dover Publications, 2000.

Reference Books:

1. A.S. Gupta, *Calculus of Variations with Applications*, Prentice-Hall of India, 2008.
2. M.L. Krasnov, G.I. Makarenko and A.I. Kiselev, *Problems and Exercises in the Calculus of Variations*, Mir Publishers, Moscow 1975.

Minor: MATH- 4221- GALOIS THEORY (4 credits)

Objectives:

To study Polynomial rings, Field theory, Splitting fields and Algebraic closures, Galois Theory and Composite extension and simple extensions.

	Course Outcome
CO 1	To study about the various extension fields and splitting field
CO 2	To study and understand about Solvable by radicals
CO 3	To learn about finite and cyclotomic fields and Wedderburn Theorem

Unit I: Field theory: Basic theory of field extensions-Algebraic Extensions.

Unit II: Splitting fields and Algebraic closures - Separable and inseparable extensions - Cyclotomic polynomials and extensions.

Unit III: Galois Theory: Basic definitions- The fundamental theorem of Galois Theory - Solvable by radicals.

Unit IV: - Galois groups over the rationales. Finite Fields- Wedderburn's theorem(First proof only)

Unit V: Classical straightedge and compass constructions, Cyclotomic extensions and Abelian extensions, Galois group of polynomials.

Text Book:

1. Abstract Algebra (Second Edition) by David S. Dummit and Richard M. Foote, Wiley Student Edition (1999) for Units I to III, (Chapter 13), (Sections 14.1 to 14.3 and 14.5-14.6).

2. Topics in Algebra by I.N. Herstin (Section 5.6 - 5.8), and (Section 7.1 -7.2).

Reference books

1. M. Artin: Algebra, Prentice-Hall of India, 1991.
2. N.Jacobson: Basic Algebra, Volumes I & II, W.H.Freeman, 1980.
3. S.Lang: Algebra, 3rd edition, Addison-Wesley, 1993.

Minor: MATH 4231: LATTICE THEORY (4 CREDITS)

Course Objectives:

1. To explain the basic theory of partially ordered sets
2. To elaborate on basics of well-ordered sets

	Course Outcome
CO 1	To apply key properties of Lattices
CO 2	To categorize the important types of lattices
CO 3	To discuss the Boolean algebras with their applications

Unit I: Partially Ordered Sets: (Chapter: 1**)**
Basic Definitions – Duality – Monotone Maps – Down-Sets and the Down Map – Height and Graded Posets – Chain Conditions – Chain Conditions and Finiteness – Dilworth's Theorem – Symmetric and Transitive Closures – The Poset of Partial Orders.

Unit II: Well- Ordered Sets: (Chapter: 2**)**
Well-Ordered Sets – Ordinal Numbers – Transfinite Induction – Cardinal Numbers – Ordinal and Cardinal Arithmetic – Complete Posets.

Unit III: Lattices: (Chapter: 3**)**
Closure and Inheritance – Semilattices – Arbitrary Meets Equivalent to Arbitrary Joins – Lattices – Meet-Structures and Closure Operators – Properties of Lattices – Irreducible Elements – Completeness – Sublattices – Denseness – Lattice Homomorphisms – Ideals and Filters – Prime and Maximal Ideals.

Unit IV: Modular and Distributive Lattices: (Chapter: 4**)**
Quadrilaterals – The definitions and Examples – Characterizations – Modularity and Semi modularity – Partition Lattices and Representations – Distributive Lattices.

Unit V:Boolean Algebras: **(**Chapter: 5**)**
Boolean Lattices – Boolean Algebras – Boolean Rings – Boolean Homomorphisms – Characterizing Boolean Lattices – Complete and Infinite Distributivity

Text Book:-

1. Steven Roman, Lattices and Ordered Sets, Springer Science, 2008.

   Chapters: 1,2,3,4,and 5.

Reference Books:-

1. Garrett Birkhoff, Lattice Theory, American Mathematical Society, Colloquim Publications, 1948.

Semester-IX

MAJOR-21 **HARD CORE: MATH 5110 - FUNCTIONAL ANALYSIS**

(4 Credits)

Objectives:

To study Normed Linear Spaces, Continuity, Equivalent norms, Hahn-Banach theorem for real vector spaces, Closed and open maps, Separable Hilbert spaces, Orthogonal projections

	Course Outcome	**Level**
CO 1	explain the concepts of normed linear space (NLS), continuity of alinear map, Lp-space, Banach, Hilbert spaces, four pillars	Remember & Understand
CO 2	demonstrate the convergence in the different types of spaces	Apply
CO 3	analyze the properties of different types NLS	Analyze
CO 4	determine the linear functional in terms orthonormal basis	Evaluate
CO 5	Obtain the open mapping theorem from closed graph theorem and vice-versa	Create

Unit-I Sections: 1.2.3, 1.2.5, 2.1, 2.1.1, 2.1.2, 2.1.4

Review of linear spaces – Linear functionals – hyperspaces – projections – Cauchy Schwarz inequality – Holder's inequality –Minkowski inequality – Normed linear spaces – Definition and examples – Basic properties – Semi norms and quotient spaces – product spaces and the graph norm.

Unit-II Sections:3.1, 3.1.1, 3.2, 3.2.1, 3.4.1, 2.2, 2.2.1, 2.2.2, 2.2.3, 2.4

Bounded linear Maps – Properties – Norm of a bounded linear Map – Banach spaces – Completeness of $l_p(1 \leq p \leq \infty), L_p[a,b], C[a,b], BV[a,b]$ – Completeness of the space of all bounded linear Maps – The completeness of the quotient space – The completion of a normed linearspace – Completeness and absolutely convergent series – Finite dimensional normed linear spaces – Riesz Lemma.

Unit-III Sections: 5.1, 5.2, 5.3, 5.4, 3.4, 6.1

The Hahn – Banach Extension Theorem anditscorollaries – The Hahn Banach Separation Theorem – Convergence of sequence of operators – The uniform Boundedness principle – The Banach Steinhauss Theorem – Weakly bounded sets – Schauder basis and separability.

Unit-IV Sections: 7.1, 7.2, 7.3, 8.1, 8.1.2

The closed graph Theorem – The bounded inverse theorem – The open mapping Theorem – The dual of $l_p(1 \leq p < \infty)$, the dual of $(C_{00}, ||.||_p)$ when $(1 \leq p < \infty)$ - The dual of $(C, \|.\|_\infty)$.

Unit-V Sections: 2.1.5, 4.1, 4.2, 4.3, 4.4, 2.5, 2.6, 3.3

Inner product spaces – Orthonormal sets –Gram Schmidt Orthogonalization process – Bessel's inequality – Hilbert spaces - Parseval's Theorem – Example of a nonseparable Hilbert space – Best approximation Theorems – Projection Theorem – Riesz Fischer Theorem – The Riesz representation Theorem.

Text Book:

1. M.Thamban Nair, *Functional Analysis: A First Course*, Prentice Hall of India, 2002.

Reference Books:

1. Joseph Muscat, *Functional Analysis*, Springer(2008).
2. BalmohanV.Limaye, *Functional Analysis*, New Age International Publishers (2014).
3. Erwin Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley(2007).
4. Martin Schecter, *Principle of Functional Analysis*, American Mathematical Society (2009)
5. BelaBollobas, *Linear Analysis:An Introductory Course*,2e, Cambridge Univ. Press (1999).
6. Bryan P. Rynne and Martin.AYoungson, *Linear Functional Analysis*, Springer (2008).

MAJOR-22 MATH 5120: PARTIAL DIFFERENTIAL EQUATIONS
(4 Credits)

Objectives:
To study first order PDEs, Non-linear first order PDEs, Classification of second order PDEs, Wave Equations**,** Laplace equations, Heat Equations.

	Course Outcome	Level
CO 1	understand the relation between the theory and modelling in the problems arising in various fields, such as, economics, finance, applied sciences and etc	Remember Understand
CO 2	Enhance their mathematical understanding in representing solutions of partial differential equations.	Apply
CO 3	classify the partial differential equations and transform into canonical form	Analyze
CO 4	determine the solution representation for the three important classes of PDEs, such as Laplace, Heat and wave equation by various methods.	Evaluate
CO 5	Formulate fundamentals of partial differential equations, like Green's function, maximum principles, Cauchy problem, to take a research career in the area of partial differential equations	Create

Unit – I: First Order PDEs

Surfaces and their Normals, Curves and tangents - Genesis of first order PDE- Classification of Integrals- Linear equations of first Order - Integral surface passing through a curve – Cauchy problem for first order PDE – Orthogonal Surfaces.

Non-linear first order PDEs : Compatible systems- Solutions of Quasi linear equations

Charpit's method- Special Types of Charpits Method, -Integral surfaces through a given curve-The Cauchy problem for Quasi Linear case and nonlinear first order PDEs.

Unit – II: Second Order PDEs

Genesis of Second order PDEs- Classification of second order PDEs- Canonical forms of Hyperbolic- Elliptic and parabolic type PDEs, Linear PDE with constant coefficients – Method of finding CF and particular integral- Homogeneous linear PDE

Unit – III **Hyperbolic PDEs / Wave Equation**

Derivation of One –dimensional wave equations- Initial Value Problem – D'Alembert Solution, Method of separation of variables, Forced Vibration, Solution of non-homogeneous equation Uniqueness of solution of wave equation.

Unit – IV: Elliptic PDEs/Laplace Equations

Derivation of Laplace equations & poisson equation- Boundary value problems- Properties of Harmonic functions- Spherical Mean, Mean value theorem- Maximum and minimum principles- Separation of variables- Dirichlet problem and Neumann problems for a rectangle and circle (Upto 2.10 in Text Book 1). Application - Irrotational Flow of an Incompressible Fluid (Section 2.13)

Unit – V: Heat Equations

Diffusion Equation, Boundary Conditions - Elementary solution- Solution by separation of variables- Classification in n-variables- Families of equipotential surfaces

Text Books

1. K. Shankara Rao, Introduction to Partial Differential Equations, PHI Publications, 3rd Edition. 2011.
2. T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa Publishing House, 2010.

Reference Books

1. I. N. Sneddon, Elements of Partial DifferentiaI Equations, McGraw Hill, International Edition, 1986.
2. F. John, Partial Differential Equations, Springer Verlag, 1975.
3. Lawrence C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, 1998.

LIST OF MINORS FOR 5th Year (ANNEXURE - II)

Minor:12-14 MATH 5111: DIFFERENTIAL GEOMETRY (4 CREDITS)

Course Objectives:

1. To learn about parametric curves, level curves and the notion of curvation of plane curves
2. To study about the properties of space curves, Serret Frenet equations and the four vertex theorem

	Course Outcome
CO 1	To study about surfaces, quadratic surfaces, triple orthogonal systems
CO 2	To calculate the length of curves on surfaces and surface area
CO 3	To study about the normal and principle curvature of curves on a surface and Euler's theorem

Unit I: [Sections: 1.1 to 1.4 and Sections 2.1,2. 2.]

Curves- arc length- Reparametrization-Level curves - Curvature - Plane curves.

Unit II: [Sections 2.3 and Sections 3.1 to 3.3.]

Space curves-Torsion- Serret Frenet equations- Simple closed curves- The Isoperimetric Inequality- The Four vertex Theorem.

Unit III: [Sections 4.1 to 4.7]

Smooth surface- Tangents, normal and orient ability- Examples of surfaces- Quadratic surfaces- Triple orthogonal systems- Applications of Inverse function theorem

Unit IV: [Sections: 5.1 to 5.5]

Lengths of curves on surfacesa- First fundamental form- Isometries of surfaces- Conformal mapping of surfaces- Surface area- Equiareal maps and a theorem of Archimedes.

Unit V: [Sections: 6.1 to 6.4]

The Second Fundamental form- The Curvature of curves on a surface- The normal and principal curvature- Euler's theorem- The geometric interpretation of principal curvatures.

Text Book:

1. Andrew Pressley, *Elementary Differential Geometry*, Springer, 2004.

Reference Books:

1. Christian Bar, *Elementary Differential Geometry*, Cambridge University Press, 2011.
2. Thomas F. Banchoff and Stephen T. Lovett, *Differential Geometry of Curves and Surfaces*, A.K Peters/CRC press, 2010.
3. W. Klingenberg, *A course in Differential Geometry*, Springer-Verlag, New York, 1978.

Minor:12-14 MATH 5121: NUMERICAL ANALYSIS FOR ORDINARY DIFFERENTIAL EQUATIONS (4 Credits)

Objectives:

To study various numerical methods to solve ordinary differential equations such as Euler's method, Gaussion quadrature and Error Control.

Unit-I

Euler's method - Trapezoidal rule - Theta method.

Unit-II

Adams - Bashforth method - Order and convergence - Backward differentiation formula.

Unit-III

Gaussion quadrature - Explicit Runge - Kutta scheme - Implicit Runge Kutta scheme - Collocation.

Unit-IV

Stiff equations - Linear stability domain and A- Stability -- A-stability of RK and multistep methods.

Unit-V

Error Control - Milne Device - Embedded Runge Kutta method.

Text Book

1. Arieh Iserles, A First Course in the Numerical Analysis of Differential Equations, Cambridge University press, 2^{nd} edition, 2008.

Reference Books:

1. Richard L. Burden and J.Douglas faires, Numerical Analysis(9^{th} Edition), Cengage Learning India, 2012.

Minor:12-14 MATH 5131: q-SERIES IN NUMBER THEORY (4 CREDITS)

Course Objectives:

1. To understand basic hypergeometric series
2. To study unilateral series

	Course Outcome
CO 1	To study bilateral series
CO 2	To study theta function identities
CO 3	To study classical theta functions

Unit I

Introduction to Basic hyper Geometric series- Bionomial theorem- q- bionomial theorem Heine's Trasformation formula- Jackson transformation formula

Unit II

Jacobi's triple product identity and its applications and Quintuple product identity and Gaussian polynomials.

Unit III

Bilateral Series- Ramanujan I Ψ 1summation and related identities- Ramanujan theta function identities involving Lambert series.

Unit IV

q- series and theta functions Entries 18 to 30 Chapter 16 of Ramnujan's notebook.

Unit V

Classical theta functions to hypergeometric series and its applications.

Text Book

1. Gasper and Rahman, Basic hyper geometric series, Cambridge University press 1990.(Unit I-III)
2. BC Berndt Ramanujans notebooks Part II Springer Verlag New York 1991.(Unit IV-V)

Minor: 12-14 MATH 5141: INTEGRAL TRANSFORMS AND THEIR APPLICATIONS (4 CREDITS)

Course Objectives:

1. To learn and understand Laplace and Hankel transforms with properties and Applications.
2. To learn and understand Mellin and Z transform with properties and Applications

	Course Outcome
CO 1	To study about Laplace transform and Inverse Laplace transform
CO 2	To study about Applications of Laplace transform
CO 3	To study Hankel transform with properties and to solve the PDE
CO 4	To study Mellin transform with properties and to solve the summation series
CO 5	To study and understand about Z- transform with properties and to apply for solving the difference equations

Unit I: Laplace Transforms (Sections-3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8)

Laplace transforms - Definition and Examples, Basic Properties of Laplace Transforms, The Convolution Theorem and Properties of Convolution, Differentiation, and Integration of Laplace Transforms. The Inverse Laplace Transform and Examples, Tauberian Theorems and Watson's Lemma.

Unit II: Applications of Laplace Transforms (Sections-4.1, 4.2, 4.3)

Applications of Laplace Transforms to the Solutions of Ordinary Differential Equations, Partial Differential Equations, Initial and Boundary Value Problems.

Unit III: Hankel Transforms (Sections-7.1, 7.2, 7.3, 7.4)

Introduction, The Hankel Transform and Examples, Operational Properties of the Hankel Transform, Applications of Hankel Transforms to Partial Differential Equations.

Unit IV: Mellin Transforms (Sections- 8.1, 8.2, 8.3, 8.4, 8.6)

Introduction, Definition of the Mellin Transform and Examples, Basic Operational Properties of Mellin Transforms, Applications of Mellin Transforms, Application of Mellin Transforms to Summation of Series.

Unit V: Z Transforms (Sections-12.1, 12.2, 12.3, 12.4, 12.5, 12.6)

Introduction, Dynamic Linear Systems and Impulse Response, Definition of the Z Transform and Examples, Basic Operational Properties of Z Transforms, The Inverse Z Transform and Examples, Applications of Z Transforms to Finite Difference Equations.

Text Book

1. Lokenath Debnath and Dambaru Bhatta, Integral Transforms and Their Applications, Third Edition, CRC Press, Taylor and Francis Group, A Chapman and Hall Book, 2015.

Reference Books:

1. Ian N. Snedden, The Use of Integral Transforms, McGraw Hill, 1972
2. B. Davies, Integral Transforms and Their Applications, Springer, Texts in Applied Mathematics 41, Third Edition,2009.
3. Alexander D. Poularikas, Transforms and Applications Handbook, Third Edition, CRC Press, Taylor and Francis Group, 2010.

Minor:12-14 MATH-5151 Wavelet Theory and Applications

(4 Credits)

Course Objectives:

1. To introduce the idea of Fourier series, Fourier transform and Wavelet theory.
2. To study the notion of MRA and some applications in real life applications

	Course Outcome
CO 1	Understand the concept of orthogonal and orthonormal bases in function spaces
CO 2	Learn Fourier transform and wavelet transform.
CO 3	Learn applications of wavelets to the real-world problems

Unit-I: Fourier Series and Fourier Transforms

Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, The complex form of Fourier series. Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Convolution. [Ruch & Patrick: 2.1,2.2, 2.3, 2.4]

Unit–II: Fourier Transforms and Wavelets

Discrete Fourier transform of a digital signal, Inverse discrete Fourier transform, Window Fourier transform, Short time Fourier transform, Admissibility condition for a wavelet, Wavelet series, Classes of wavelets: Haar, Morlet, Maxican hat, Meyer and Daubechies wavelets; Wavelets with compact support. [Chui: 3.1, 3.2, 3.3, 3.4, 3.6]

Unit-III: Haar Scaling Function and Wavelet, Time-Frequency Analysis

Orthogonal functions, Orthonormal functions, Function spaces, Orthogonal basis functions, Haar scaling function, Haar spaces: Haar space V_0, general Haar space V_j; Haar wavelet, Haar wavelet spaces: Haar wavelet space W_0, general Haar wavelet space W_j; Decomposition and reconstruction, Time-frequency analysis, Orthogonal and orthonormal bases. [Ruch & Patrick: 3.1,3.2, 3.3, 3.4, 3.5]

Unit–IV: Discrete Wavelet Transforms

Stationary and non-stationary signals, Haar transform, 1-level Haar transform, Multi-level Haar transform, Conservation and compaction of energy, Multiresolution analysis, Decomposition and reconstruction of signals using discrete wavelet transform (DWT). [Primer: Ch2: 2.1, 2.2, 2.3, 2.4

Unit–V: Applications

Multiresolution analysis, Applications in signal compression, Analysis and classification of signals using DWT, Signal de-noising: Image and ECG signals. [Ruch & Patrick: 5.1, 4.1, 4.2, 4.6, 4.8, 4.9]

Text Books:

1. Charles K. Chui (1992). *An Introduction to Wavelets*. Academic Press.
2. David K. Ruch & Patrick J. Van Fleet (2009), *Wavelet Theory*: *An Elementary Approach with Applications*. John Wiley & Sons.
3. James S. Walker (2008). *A Primer on Wavelets and Their Scientific Applications* (2nd edition). Chapman & Hall/CRC, Taylor & Francis.

References:

1. Ingrid Daubechies (1999). *Ten Lectures on Wavelets*. SIAM
2. Michael W. Frazier (1999). *An Introduction to Wavelets Through Linear Algebra*. Springer-Verlag.
3. Stéphane Mallat (2008). *A Wavelet Tour of Signal Processing* (3rd edition). Academic Press.

David F. Walnut (2008), An Introduction to Wavelet Analysis, Springer, 2008.

Minor:12-14 MATH-5161 GRAPHS AND ALGEBRAS

(4 Credits)

Unit-I: **Algebraic structures from graphs**: Isomorphism of graphs – Isomorphism as a relation – Automorphism of graphs – Graphs and Groups –The spectrum of a graph – Characteristic polynomial – Adjacency Algebra.

Unit-II: **Graphs defined on groups:** Cayley Graph – Circulant graph – Power graph – Commuting graph, commuting graph – Non-generating graph – Nilpotence graph – Solvability graph – Engel graph – Aut(G)-invariant graph.

Unit-III: **Graphs defined on rings**: Zero-divisor Graph of a ring-Introduction – Basic Properties of zero-divisor Graphs – Total graph of a ring- Introduction – Basic properties of total graphs.

Unit-IV: **Properties of Graphs defined on rings**: Girth of zero-divisor graph of a commutative ring – Diameter of zero-divisor graph of a commutative ring – Girth of total Graph of a commutative ring – Diameter of total graph of a commutative ring.

Unit-V: **More graphs on rings**: Cayley graphs – Co-maximal graphs – Unit graphs – Cozero-divisor graphs – Jacobson graphs – Intersection graphs – Annihilator graphs.

Text Book:-

1. Gary Chartrand, Ping Zhang, Introduction to Graph Theory, Tata McGraw-Hill, 2006. (Unit-I)
2. Norman Biggs, Algbraic Graph Theory, Second Edition, Cambridge University Press, 1993. (Unit-I)
3. Peter J. Cameron, Graphs defined on groups, International Journal of Group Theory, 11(2), 2022, 53-107. (Unit-II)
4. David F. Anderson, T. Asir, Ayman Badawi, T. Tamizh Chelvam, Graphs from rings, Springer Switzerland, 2021. (Unit-III,IV,V)

Reference Books:-

1. Chris Godsil and Gordon Royle, Algebraic Graph Theory, Springer 2009.
2. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory (Universitext), Second Edition, Springer New York, 2012.

Minor: 12-14 MATH-5171: Probability and Statistics (4 Credits)

Objectives:

To study the basics of Probability density function, Special distributions, Distributions of functions of random variables, Sampling theory and Statistical inference.

Unit I: The probability set function – Random variables – Probability density function – Distribution function – Mathematical expectation – Special mathematical expectations – Chebyshev's Inequality – Conditional probability – Marginal and conditional distributions – Stochastic independence. *[Chapters 1 and 2 (except 1.1and 1.2) of the text book]*

Unit II: Some special distributions: The Binomial and related distributions – The Poisson distribution – The Gamma and Chi-Square Distributions – The Normal distribution- The Bivariate normal distribution. *[Chapter -3 of the text book]*

Unit III: Distributions of functions of random variables - Sampling theory – Transformations of variables of the discrete type – Transformations of variables of the continuous type – The b, t and F distributions- Distributions of order statistics- The moment generating function technique. *[Chapter 4 [sections 4.1 to 4.7] of the text book.]*

Unit IV: The distributions of $\bar{X}$ and nS^2/σ^2 - Expectations of functions of random variables – Limiting distributions: Limiting moment generating functions – The Central limit theorem. *[Chapter-4 [sections 4.8 and 4.9] and Chapter-5 of the text book.]*

Unit V: Introduction to statistical inference: Point Estimation – Confidence intervals for means – Confidence intervals for differences of means - Confidence intervals for variances. *[Chapter-6 of the text book]*

Text Book:

Robert V. Hogg and Allen T. Craig , *Introduction to Mathematical Statistics* (Fifth Edition) Pearson Education, 2005.

Reference Books:

1. Paul L.Meyar, *Introductory to Probability and Statistical Applications*, Oxford&IBH Publishers Co. Pvt .Ltd, 1969.
2. Arnold Naiman, Gene Zirkel and Robert Rosenfield, *Understanding Statistics*, McGraw- Hill, 1986.
3. William Feller, *An Introduction to Probability Theory and its Applications, Vol.I*, John Wiley, Third Edition, 2008.
4. A.Mood, F.Graybill, and D.Boes, *Introduction to the Theory of Statistics*, Tata McGraw Hill (Third Edition) 2008.

Minor:15-19 MATH 5211: ALGEBRAIC NUMBER THEORY (4 CREDITS)

Course Objectives:

1. To study about the application of unique factorization in integers
2. To find the primes of Gaussian integers

	Course Outcome
CO 1	Construction of transcendental numbers using Liouville's theorem
CO 2	To study about the integral basis and discriminant of algebraic number fields
CO 3	To study about Dedekind domains.

Unit I: Elementary Number Theory (Sections 1.1 and 1.2)

Integers – Greatest common divisor – Infinitude of primes – Unique factorization in Z – Fermat's little theorem – Euler's Φ function and Euler's theorem – Multiplicative property of Φ function – Applications of unique factorization – The equation $x^2 + y^2 = z^2$ – The equation $x^4 + y^4 = z^2$ – The equation $x^4 – y^4 = z^2$ – Fermat numbers and their properties.

Unit II: Euclidean Rings(Sections 2.1, 2.2 and 2.3)

Preliminaries: Units, Associates, Irreducible elements, Norm map, Unique factorization domain, Principal ideal domain, Euclidean domain – Gauss' lemma – Gaussian integers – Units and primes in the ring of Gaussian integers – Eisenstein integers – Units in the ring of Eisenstein integers – Factorization of 3 – Order of $Z [\rho] / (\lambda)$.

Unit III: Algebraic Numbers and Integers (Sections 3.1, 3.2 and 3.3)

Basic concepts – Algebraic number – Algebraic integer – Minimal polynomial Count ability of algebraic numbers – Liouville's theorem for R – Algebraic number fields – Theorem of the primitive element –Liouville's theorem for C – Characterization of algebraic integers.

Unit IV: Integral Bases (Sections 4.1, 4.2 and 4.3)

The norm and the trace – Integral basis for an algebraic number field – Algebraic integers of Q (√ – 5) – Existence of an integral basis – Discriminant of an algebraic number field – Index – Determination of an integral basis for the ring of integers of a quadratic number field.

Unit V: Dedekind Domains (Sections 5.1 and 5.2)

Integral closure – Integrally closed ring – Noetherian ring – Dedekind domain – Characterizing Dedekind domains.

Text Book

J. E. Smonde and M. RamMurty, Problems in Algebraic Number Theory,
Graduate Texts in Mathematics, Volume 190, Springer Verlag, New York,1999.

Reference Books:

1. Pierre Samuel and Allan J Silberger, Algebraic Theory of Numbers, Dover Pub. Inc, 2008.

Minor:15-19 MATH 5221: ADVANCED TOPICS IN TOPOLOGY AND ANALYSIS (4 CREDITS)

Course Objectives:

1. To study metrization theorem.
2. To study about the dual of $L^p[a,b]$.

	Course Outcome
CO 1	To learn the quotient topology and path connectedness
CO 2	To learn Urysohn Metrization theorem and compactification
CO 3	To learn about the completeness of $L^p[a,b]$

Unit I: (Sections 22,25, relevant parts from section 24 of [1])

Quotient topology and quotient maps - Examples of quotient spaces - Path connectedness - Standard results - Example of a connected but not path connected space- Locally connected spaces.

Unit-II: (Sections29, 34,38, 43,44 of [1])

The Uryshon's metrization theorem – Locally compact spaces-One point compactification - Stone- Cech compactification – The uniform metrric on Y^J and the Space filling curve.

Unit-III: (Sections 39, 40,41 of [1])

Local finiteness- Countably locally finite refinement of open coverings of metric spaces – Paracompactness - Standard results - Metric spaces are paracompact.

Unit-IV: (Chapter:7 of [2])

L^p- spaces – Completeness - Dual of $L^p[a,b]$for $1 \leq p < \infty$.

Unit-V: (Sections 8.1, 8.2 and 8.3 from Chapter:8 of [2])

Weak sequential convergence of $L^p[a,b]$ – the Riemann Lebesgue lemma – the Radon Riesz theorem - weak sequential compactness of $L^p[a,b]$.

Text Books:

1. James R. Munkres, Topology by James R. Munkres, Pearson, 2nd edition, 2000.
2. H.L.Royden, and P.M. Fitzpatrick, Real Analysis, (Fourth Edition) PHI Learning Private Limited, 2013.

Reference Books:

1. James Dugundji, General Topology, Allyn and Bacon, Inc.(1966).
2. Inder K. Rana, *An Introduction to Measure Theory and Integration, (2e)*, Narosa (2007).
3. B.V. Limaye, Functional Analysis, Wiley Eastern, New Delhi, 1981.

Minor:15-19 MATH 5231: ADVANCED TOPOLOGY
(4 CREDITS)

Course Objectives:

1. To study about the notions of local connectedness, local compactness and one point compactification
2. We study about nets, filters and quotient topology

	Course Outcome
CO 1	We study about Stone -Cech Compactification and some Metrization theorems
CO 2	To learn about space filling curve and the imbedding theorem for compact metrizable spaces
CO 3	To study about fundamental groups and covering spaces

Unit I: (Sections- 25 and 29 of [1])
Connected components- Local connectedness - Locally path connected spaces- Local compactness, One point Compactification, Uryshon Metrization Theorem.

Unit II:(Chapter-10 of [2] and Sections- 22 and 36 of [1])
Nets and Filters- Quotient topology- Introduction to topological groups.

Unit III:(Sections-38, 39, 40, 41 and 42 of [1])
The Stone -Cech Compactification- Locally finite spaces- Nagata- Smirnov Metrization theorem- Paracompactness- Smirnov Metrization theorem.

Unit IV: (Sections-44 48 and 49 of [1])
The Peano space-filling curve – Barie Spaces – Nowhere differentiable functions.

Unit V: (Sections 48, 49, of [1])
Homotopy of paths- The fundamental group- Covering spaces- The fundamental group of the circle.

Text Books:

1. James R. Munkres, Topology, Second edition, Pearson Education Inc.,(2002).
2. K.D.Joshi, Introduction to General Topology, First edition (revised), New Age International Publishers, 2004.

Reference Books:

1. Stephen Willard, General Topology, Dover, 2004.

Minor:15-19 MATH 5241: COMMUTATIVE ALGEBRA (4 Credits)

Objectives:
To study the basics of Prime ideals, Operation on sub-modules, Tensor product and Noetherian rings.

Unit-I
Prime ideals- Maximal ideas- Nil radical- Jacobson radical- Operation on ideals- Extension and contraction.

Unit-II
Operation on sub-modules- Direct sum and product- Finitely generated modules- Exact sequences- Tensor product- Restriction and extension of Scalars.

Unit-III
Rings and Modules of Faction and Primary decomposition Local properties extended and contracted Primary decomposition.

Unit-IV
Integral dependence and chain conditions.

Unit -V
Noetherian rings and Artinian rings

Text Book
M. K. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison-Weseley, 1994.

Reference Books

1. H. Matsumura, Commutative Ring Theory, Cambridge University Press,1989.
2. I. Kaplansky, Commuatavie Rings, University of London press,1966.
3. O. Zariski and P. Samuel, Commutative Algebra, Springer 1976.

Minor:15-19 MATH-5251 DISCRETE DYNAMICAL SYSTEMS (4 Credits)

Objectives:

To study the basics of Orbits, Symbolic dynamics, Topological Conjugacy and The dynamics of Complex functions.

Unit-I

Orbits - Phase portraits- Periodic points and stable sets. Sarkovskii's theorem

Unit-II

Attracting and repelling periodic points- Differentiability and its implications – Parametrized family of functions and bifurcations- The logistic map.

Unit-III

Symbolic dynamics - Devaney's definition of Chaos - Topological Conjugacy.

Unit-IV

Newton's method-Numerical solutions of differential equations.

Unit-V

The dynamics of Complex functions- The quadratic family and the Mandelbrot set.

Text Book

Richard A. Holmgren, A First Course in Discrete Dynamical Systems, Springer Verlag (1994).

Unit-I [Chapters: 1, 2, 4 and 5], Unit-II [Chapters: 6, 7 and 8], Unit-III [Chapters: 9, 10 and 11], Unit-IV [Chapters: 12 and 13], Unit-V [Chapters 14 and 15].

Reference Books:

1. Robert L.Devaney, A First Course in Chaotic Dynamical Systems, Addison-Wesley Publishing Company, Inc. 1992.

Minor: 15-19 MATH-5261 ADVANCED SEPCIAL FUNCTIONS

(4 Credits)

Course Objectives:

1. To learn and understand about generalized hypergeometric function and their properties
2. To learn and understand about Laguree and Hermite polynomials including properties

1.

	Course Outcome
CO 1	To study and discuss about GHF and various properties and summation formulas
CO 2	To study about Laguree Polynomials and Hermite Polynomials their properties
CO 3	To study about Appell hypergoemetric function of two variables with properties

Unit I: (Chapter 4)
Basics and Introduction to Gauss's hypergeometric and Confluent hypergeometric functions, integral representations, differentiation formulas, transformation formulas, contiguous function relations, summations formulas. **(12 hours)**

Unit- II (Chapter 5)
Generalized Hypergeometric Functions: The function pFq, The contiguous function relations, A simple integral, The pFq with unit argument, Saalschutz' theorem, Whipple's, Dixon's, **(12 hours)**

Unit- III (Chapter 11)
Hermite Polynomials- Definition, recurrence relation, Rodrigues formula, orthogonality property, generating relations and general properties. **(12 hours)**

Unit IV (Chapter 12)
Laguree Polynomials-. Definition, recurrence relation, Rodrigues formula, orthogonality property, generating relations and general properties **(12 hours)**

Unit V: (Chapter 9 of Ref 2)

Appell's hypergoemtric function of two variables, Transformation formulas, integral representation of Euler and Laplace type **(12 hours)**

Text Books :

1. E. D. Rainville, Special functions, Macmillan, New York, 1960. (Chapter 5)
2. W.N. Bailey, Generalized Hypergeometric Series, Cambridge University Press, Cambridge, (1935)

Reference Books:

1. W.N. Bailey, Generalized Hypergeometric Series, Cambridge University Press, Cambridge, (1935)
2..L.J. Sater, Generalized Hypergeometric function, Cambridge University Press, London and New York, 1966

Minor: 15-19 MATH-5271 ADVANCED FUNCTIONAL ANALYSIS
(4 CREDIT)

Objectives:
To study the basics of Canonical isometry, Compact operators, Eigen values and the eigen spectrum of a linear operator, The adjoint of an operator and Spectral results for Hilbert's space operators.

Unit-I
Duals of $C[a,b]$ and $L_p[a,b]$– Separability – The Canonical isometry – The transpose of a bounded linear Map – Reflexivity – Weak convergence – Schur's Lemma – EberleinShmulyan Theorem – Best approximation in reflexive spaces.
Unit-II
Compact operators – Examples – Properties – The completeness of the space of compact operators – Compactness of the transpose.
Unit-III
Eigen values and the eigen spectrum of a linear operator – examples – spectrum and resolvent set – Spectral radius – Spectral Mapping Theorem – Resolvent Identity – The specrtral radius formula – The RieszSchauder Theory.
Unit-IV
The adjoint of an operator – Existence – Compactness of the adjoint operator – Sesquilinearfunctionals – Closed range Theorem.
Unit-V
Self-adjoint, normal, unitary operators – Numerical range and numerical radius – Spectral results for Hilbert's space operators – Properties of the Spectrum.
Text Book:
1. M.Thamban Nair, *Functional Analysis: A First Course*, Prentice Hall of India, 2002.

Unit-I	Sections: 8.1.3, 8.1.4, 8.2.1, 8.2.2,8.2.3
Unit-II	Sections: 9.1, 9.2, 9.3
Unit-III	Sections: 10.1, 10.2, 10.2.1, 10.2.2, 10.2.3, 10.4
Unit-IV	Sections: 11.1, 11.1.1, 11.1.2
Unit-V	Sections: 11.2, 12.1, 12.1.1, 12.2

Reference Books:

1. Joseph Muscat, *Functional Analysis*, Springer (2008).
2. BalmohanV.Limaye, *Functional Analysis*,3e, New Age International Publishers (2014).
1. Erwin Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley (2007).
2. Martin Schecter, *Principles of Functional Analysis*, American Mathematical Society (2009)
3. BelaBollobas, *Linear Analysis: An Introductory Course*,2e, Cambridge Univ. Press (1999).
4. Bryan P. Rynne and Martin.AYoungson, *Linear Functional Analysis*, Springer (2008).

Minor: 15-19 **MATH-5281 NON-COMMUTATIVE RINGS AND REPRESENTATIONS (4 Credits)**

Objectives:

To study the basics of Modules, Semi simple rings, Structure theory of ring and substantial study of Representations.

Unit-I Modules

Modules - Artinian and Notherian modules - Tensor products - Restricted and induced modules. - Indecomposable modules – Completely reducible module - Schur Lemma.

Unit-II Radical

Semi simple rings - The radical of a rings – The properties of Jacobson radical

Unit-III Group algebras - The Jacabson radical of Group Algebra – Maschke's Theorem.

Unit-IV Structure theory

Structure theory of ring - Density theorem - Widderburn-Artin theorem for semi simple rings.

Unit-V Representations

Representations - linear representation - Matrix representation - Equivalent representation - Invariant subspaces - Irreducible representations - Direct sum of representations - Induced representation – restricted representation - Tensor product of representations - Inner products of representation.

Text Book

1. I. N Herstein, Non-Commutative Rings, The Mathematical Association of America, 5th Edition, 2005 (Chapter 1: Units I-III, Chapter 2: Unit IV and Chapter 5: Unit V)

Reference Books:

1. William Fulton and Joe Harris, Representation Theory - A First Course, Springer International Edition, Springer-Verlag, New York, 2004.
2. Jacobson, Basic Algebra II, Hindustan Publishing Corporation (India), 1983.
3. Charles W. Curtis and Irving Reiner, Representation Theory of Finite Groups and Associative Algebras, Inter Science Publishers, 1962.

Minor: 15-19 MATH-5291: ALGEBRAIC GRAPH THEORY (4 Credits)

Objectives:

To study the objectives of Linear Algebra in Graph Theory, Spanning Trees and Associated Structures, The Multiplicative Expansion and Chromatic Polynomial.

Unit -I: Linear Algebra in Graph Theory – The Spectrum of a Graph – Characteristic polynomial – Adjacency Algebra - Reduction Formula for χ – Regular Graphs and Line Graphs – Circulant Graph – Spectrum of the Strongly Regular Graph – Cycles and Cuts – The Incidence Matrix – The Laplacian Spectrum.

Unit -II: Spanning Trees and Associated Structures – Kirchhoff's Law – Thomson's Principle – The Tree-Number – A Bound for the Tree Number of Regular Graphs – Determinant Expansions – Elementary Graphs.

Unit -III: Vertex-Partition and the Spectrum – Color Partition – Wilf's Theorem on the Chromatic Number of a Graph – Coloring Problems – The Chromatic Polynomial – Recursive Relation for the Chromatic Polynomial – Quasi-Separable Graphs – Subgraph Expansions – The Rank Polynomial.

Unit -IV: The Multiplicative Expansion – Whitney's Theorem on Counting Subgraphs – The Induced Subgraph Expansion – Baker's Theorem.

Unit -V: The Tutte Polynomial – The λ-operator – The Deletion-Contraction Property – Chromatic Polynomial and Spanning Trees – The Chromatic Invariant.

Text Book:-

1. Norman Biggs, Algbraic Graph Theory, Second Edition, Cambridge University Press, 1993.

Reference Books:-

1. Chris Godsil and Gordon Royle, Algebraic Graph Theory, Springer 2009.
2. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory (Universitext), Second Edition, Springer New York 2012.

MULTIDISPLINARY COURSE

MATH 1112: BASIC MATHEMATICS
(3 CREDITS)

Course Object:

To learn the basic of Mathematical logics, combinatorics and the algebra of matrices.

CO 3	To introduce the idea of matrices and learn above
CO 4	To introduce the basic concept of permutation-Combinations
CO 5	The learn logics, truth table and basic set theory.

Unit I:
Linear System – Matrices – dot Product – Matrix multiplication – properties of Matrix operations – Matrix transformation.

Unit II:
Solution of linear system of equations – row echelon form – reduced row echelon form – Polynomial interpolation – inverse of a matrix – linear systems.

Unit III:
Logic – truth table – algebra of propositions- logical arguments – sets- operations on sets.

Unit IV:
Principle of inclusion – exclusion – the addition and multiplication rules – pigeonhole principles.

Unit V:
Permutations – Combinations – Elementary Probability.

Text Book:

1. Bernard Kolman, Dred. R. Hill, Introductory Linear Algebra, 8th edition – peasson, India 2011.
2. Edgar G. Goodaire, Michael. M. Parmenter, Discrete Mathematics with Graph Theory, 3e PHI, India, 2011.

NEP MINOR COURSES
[to other departments]

Minor: MATH-1111: BASIC CALCULUS (4 CREDITS)

Course Objectives:

1. Able to Analyze the Derivatives of functions.
2. To understand the idea of applications of Derivatives

	Course Outcome
CO 1	To solve Asymptotes, concavity & convexity point of inflexion
CO 2	Able to solve differentiation using Leibnitz rule
CO 3	To determine the Exponent and Logarithmic functions

Unit I:

Quick review of Derivative of some familiar functions Application of Derivatives - Increasing decreasing functions - Maxima minima-Error –Approximation- Optimization-Newton method- Mean value theorems.

Unit II:

Asymptotes- Test of concavity& convexity point of inflexion- Multiple point training curves in Cartesian & Polar co-ordinates. Successive differentiation- Leibnitz rule- Problems and examples.

Unit III:

Definite integrals - Properties of definite integrals - Integral as the limits of a sum- Evaluation of integrals- Area and the mean value theorem-The fundamental theorem(without proof)- Substitution in definite integrals.

Unit IV:

Integration by parts (theorem and examples) – Integration of rational fractions-Reduction formulas.

Unit V:

Areas between curves- Finding volume by slicing- Volumes of solids of revolution - Disk and washers- Cylindrical shell- Lengths of plane curves- Areas of surface of revolution.

Text Book

2. George B.Thomas, Maurice D.Weir and Joel Hass, Thomas' Calculus 12th Edition, Pearson Education, 2015.

Reference Books

6. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Vol.I, Springer 1999.
7. Serge Lang A First course in Calculus 5th edition, Springer, 1999.
8. N. P. Bali, Integral Calculus, Laxmi Publications, Delhi 1991.
9. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Volumes I & II Springer, SIE, 2004.
10. Serge Lang A First course in Calculus 5th edition, Springer, 1999.

Minor: MATH-1211: BASIC ALGEBRA AND THEORY OF EQUATIONS (4 CREDITS)

Course Objectives:

1. To introduce the idea of matrices and to learn about the algebra of matrices
2. To solve system linear equations using matrix Theory

	Course Outcome
CO 1	To learn the relation between the co-efficient and roots of polynomial equations.
CO 2	To learn various methods for solving polynomial equations and study the nature & position of roots.
CO 3	Analytic Methods for solving the polynomial equation of degrees 3 & 4.

Unit I: (Sections 1.1, 1.2, 1.3,1.4,1.5 of [1])

Linear systems - Matrices - Dot product and Matrix multiplication - Properties of Matrix operation, Matrix transformations.

Unit II: (Sections 1.6,1.7,1.8[1])

Solutions of Linear systems of equations - Row echelon from reduced row echelon form – Polynomial interpolation - The inverse of a Matrix. - Linear Systems and inverses - LU- Factorization Method.

Unit III: (Sections 5.1,5-2,.5.3 of [2])

Division algorithm - Relation between roots and coefficients - Sum of the powers of the roots.

Unit IV: (section 5.4,5.5,5.6 ,5.7 of [2])

Reciprocal equations - Transformation of equations: - Multiple roots - Nature of position of roots - Sturm's Theorem.

Unit V: (Sections 5.8,5.9,5.10 of [2])

Cardan’s Method for solving Cubic equations – Ferrari’s Method for solving biquadratic equations - New Newton's Method- Horner's Method

Text Books

1. Bernard Kolman Drid R. Hill, Introductory Linear Algebra, (8e),Pearson India (2011)
3. S. Arumugam and A Thangaand Isaac, Set Theory Number System and Theory of Equations, New Gamma publishing house(1997.).

References:

1. Theory of Equations, Hari Kishan, Atlantic Publishers, 2022
2.Theory of Equations, Lalji Prasad, New Revised Edition, 2016

Minor: MATH-2111: FUNDAMENTALS OF REAL ANALYSIS
(4 CREDITS)

Course Object:

1. To study the importance of the lub property of the real number system
2. To study the property of convergence sequence

CO 3	To learn some applications of differentiability of functions
CO 4	To introduce the Riemann theory of integration and the fundamental theorem of calculus
CO 5	To learn about pointwise and uniform convergences of sequence of functions

Unit I:[Sections: 3.1, 3.2, 3.3, 3.4]

Convergent sequence Examples – convergent sequences – Limit Theorems – Monotoriesequences Bolzano – Weinerstrars Theorem.

Unit II: [Sections: 3.7, 9.2, 9.3]

Infinite Series – The Cauchy criterion - Examples - Comparison Test - Limit Comparison Test - The Canchy Condensation Test - Absolute Convergence - The root Test – The ratio Test - The Integral Test- Alternating Serier Test - Abel's Test.

Unit III: [Sections: 4.1 4.2, 4, 3].

Limits of function – Examples – Sequence version of the limit of a function - Limit Theorems -One-sided limits.

Unit IV: [Sections: 5.1,5-2, 5·3]

Continuous functions - Examples – Algebra - Continuous functions on intervals - Continuous functions - Intervals Maximum Minimum Theorem – Location of Roots Theorem – Bolzanos Intermediate value theorem

Unit V: [Sections: 6.1,6.2,6.4]

Differentiable functions - Algebra of differentiable functions – Chain Rule - Interior Extremum Theorem - Rolle's Theorem -Mean value Theorem - First derivative Test - Darboux's Theorem - Taylor's Theorem.

Text book:

R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis 4e Wiley India, 2016.

Reference Books

1. Richard R Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt Ltd, New Delhi, Indian Edition 1970.
2. Kenneth A. Ross, *Elementary Analysis: The Theory of Calculus*, springer, 2e (2013).

Minor: MATH-2211: INTRODUCTION TO DIFFERENTIAL EQUATIONS (4 CREDITS)

Course Objectives:

1. To understand ordinary and first order partial differential equations and their applications
2. To understand the first and second order ordinary differential equations and their solution procedures.

	Course Outcome
CO 1	To solve a system of first order ODEs
CO 2	To analyze the stability of a Dynamical System using Differential Equations and their solutions
CO 3	To Solve First Order Partial Differential Equations

Unit I: [Sections 1.5-1.8 from [1]**]**

Exact differential equations- Integrating factors – Linear differential equations- Bernoulli equation – Modeling: Electric circuits – Orthogonal trajectories of curves.

Unit II: [Sections 2.1-2.7 from [1]**]**

Homogeneous linear equations of second order – Second order homogeneous equations with constant coefficients – Case of complex roots- Complex exponential function – Differential operators – Modeling: Free oscillations – Euler-Cauchy equation – Existence and uniqueness theory – Wronskian.

Unit III: [Sections 2.8-2.10, 2.13, 2.14 from [1]]

Non homogeneous equations – Solution by undetermined coefficients – Solution by variation of parameters – Modeling of electric circuits – Higher order linear differential equations – Higher order homogeneous equations with constant coefficients.

Unit IV: [Sections 3.0-3.4 from [1]]

Introduction: vectors, matrices, eigenvalues – Introductory examples – Basic concepts and theory – Homogeneous systems with constant coefficients, phase plane, critical points – Criteria for critical points, Stability.

Unit V: Chapter 1 from [2]

Non-linear first order PDEs : Compatible systems- Solutions of Quasi linear equations

Charpit's method - Special Types of Charpits Method,

Text Book

1. Erwin Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, 1999.

2. K. Shankara Rao, Introduction to Partial Differential Equations, PHI Publications, 3rd Edition. 2011. – Chapter 1

Reference Books

1. George F. Simmons, Differential Equations, Tata McGraw-Hill, New Delhi, 1972.
2. Boyce and Di Prima, Differential Equations and Boundary Value Problems, Wiley,10th edition 2012.
3. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall of India Private Ltd, 1991.

Minor: MATH-3111: CALCULUS OF SEVERAL VARIABLES (4 CREDITS)

Course Objectives:

1. To learn about differentiation, partial differentiation and to calculate directional derivatives and gradients
2. To learn about maxima and minima of two and more variables.

	Course Outcome
CO 1	To apply the double and triple integrals to find volume and area of curves
CO 2	To apply line and surface integrals for computing over curves and surface
CO 3	To learn about integral theorems in vector calculus

Unit I: [Sections: 14.1, 14,2,14,3 and 14.4]

Functions of several variables-Level set and graphs-Limit and continuity-Two path test for nonexistence of a limit-Partial derivatives-The chain rule..

Unit II: **[Sections: 14.5, 14.6, 14.7 and 14.8]**

Directional derivatives and gradient vectors- Gradients and tangents to level curves- Tangent planes and normal lines- Linear approximation- Extreme values and saddle points- Second derivative test for local extrema-Lagrange multipliers.

Unit III: [Sections: 14.10, 15.1 and 15.2]

Taylor's formula for two variables- Double integral over rectangles- Fubini's Theorem for calculating double integrals- Area, moments and centre of mass

Unit IV: [Sections: 15.3, 15.4 and 15.5]

Double integrals in polar form-Changing Cartesian integrals into polar integrals- Finding area in polar coordinates – Triple integrals in rectangular coordinates- Volume in triple integrals – Mass and moments in three dimensions.

Unit V: [**Sections: 15.6 and 15.7**]

Triple integrals in Cylindrical and spherical coordinates- Changing the order of integration in cylindrical and spherical coordinates.

Text Book:

George B. Thomas, Maurice D Weir, Joel Hass , Frank R Giordono, ***Thomas calculus 11e,*** Pearson India.

Reference Books:

1. Howard Anton, Irl Bivens, Stephens Davis, ***Calculus*** 10e, Wiley India.
2. James Stewart, ***Calculus, Early Transendentals,*** 7e CENGAGE India.

Minor: MATH-3211: INTRODUCTION TO LINEAR ALGEBRA
(4 CREDITS)

Course Objectives:

1. To understand linear transformations Characteristic roots- Similarity of linear transformations and matrices.

	Course Outcome
CO 1	To understand vector spaces, basis and dimensions
CO 2	To understand Matrices and their Trace- Transpose & Determinants.
CO 3	To understand Inner product and orthogonality

Unit I: [Sections 1.2 to 1.6**]**
Abstract Algebra Concepts – Groups- Subgroups- Fields- examples Vector space- Subspace-linear combinations and systems of linear equations- Linear dependence and linear independence- Basis and dimension.

Unit II: [Sections 2.1 to 2.5**]**
Linear Transformations- Null spaces- Range spaces- Dimension theorem- Matrix representation of linear transformation- composition of linear transformations and Matrix multiplication- Invert ability and Isomorphism- The change of coordinate matrix.

Unit III: [Sections 3.1 to 3.4**]**
Elementary matrix Operations and elementary matrices- The rank of a matrix and matrix inverses- systems of linear equations- Theory and computation

Unit IV: [Sections 4.1 to 4.4 and 5.1 to 5.2, 5.4**]**
Determinants of order 2 and order n- propertie4s of determinants- Important facts about determinants- Eigen values and Eigen vectors- Diagonalizability- Invariant spaces and Cayley- Hamilton theorem.

Unit V: [Sections 6.1, 6.2**]**
Inner products and norms- The Gram-Schmidt orthogonalization process and orthogonal complements.

Text Book
Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, Linear Algebra, 4th Edition,
Printice Hall of India Pvt. Ltd., 2006

Reference Book

1. S. Kumaresan, Linear Algebra Geometric Approach, Prentice Hall of India Pvt. Ltd., 2000.
2. I. N. Herstin, Topics in Algebra, 2nd Edition, John Wiley & Sons, 2003.

Minor: MATH-4111: VECTOR CALCULUS(4 CREDITS)

Course Objectives:

1. To learn about curvature and torsion of a space curve.
2. To learn about the fundamental theorems by Green, Stoke and Gauss..

	Course Outcome
CO 1	To apply the double and triple integrals to find volume and area of curves
CO 2	To apply line and surface integrals for computing over curves and surface
CO 3	To learn about integral theorems in vector calculus

Unit I: [Sections: 13.1, 13,2,13,3, 13.4 and 13.5]
Vector functions- Modelling projectile motion- Arc length and the unit tangent vector- Curvature and the unit normal vector- Torsion and the unit binormal vector.

Unit II: **[Sections: 16.1 and 16.2]**
Line integrals- Mass and moment calculations- Vector fields- work, circulation and flux- Gradient vector field- work over a smooth curve- Flow integrals and circulation for velocity fields- Flux across a plane- Flux across a smooth closed curve..

Unit III: [Sections: 16.3 and 16.4]
Path dependence of line integrals – The fundamental Theorem of line integrals- Exact differential forms- Green's Theorem in the plane (normal form and tangential form)-Divergenc(flux density)-The Green's Theorem area formula.

Unit IV: [Sections: 16.5, and 16.6]
Surface area and surface integrals- Orientation- Moments and masses of thin shells- Flux across a surface- Parametrized surfaces- Area of a smooth surface- Parametric surface integral- Finding the center of mass.

Unit V: [**Sections: 16.7 and 16.8**]
The Curl of a vector field- Stoke's Theorem- Conservative fields and Stoke's theorem – The Divergence Theorem- The proof of divergence theorem for special regions- Properties of Curl and divergence.

Text Book:

George B. Thomas, Maurice D Weir, Joel Hass , Frank R Giordono, ***Thomas calculus 11e,*** Pearson India.

Reference Books:

1. Howard Anton, Irl Bivens, Stephens Davis, ***Calculus*** 10e, Wiley India.
2. James Stewart, ***Calculus, Early Transendentals,*** 7e CENGAGE India.

Minor: MATH-4211: INTRODUCTION TO COMPLEX ANALYSIS

Course Objectives:

1. To study and learn analytic functions and the theory of power series
2. To understand and learn about the conformal mappings and elementary transformations

	Course Outcome
CO 3	To study and learn line integrals, Cauchy's theorem and Cauchy's integral formula
CO 4	To classify zeros and poles and understand Maximum principle
CO 5	To find residues and evaluate complex integrals and definite integrals using the residue theorem and to represent functions as Taylor and Laurent series

Unit I: [Sections 12.1-12.5;**]**
Complex numbers- Complex plane - Polar form of complex numbers- Powers and roots – Derivative- Analytic function - Cauchy- Riemann equations. Laplace's equation - Geometry of Analytic Functions- Conformal mapping.
Unit II: [Sections 12.6-12.9;]
Exponential function - Trigonometric functions- Hyperbolic functions – Logarithm- General power - Linear fractional transformation.
Unit III: [Sections 13.1-13.4**]**
Line integral in the complex plane - Cauchy's integral theorem - Cauchy's integral formula - Derivatives of analytic functions.
Unit IV: [Sections 14.1-14.4**]**
Sequences- Series- Convergence tests - Power series - Functions given by power series - Taylor series and maclaurin Series
Unit V: [Sections 15.1-15.4**]**
Laurent series - Singularities and zeros, Infinity - Residue integration method evaluation of real integrals.

Text Book:
Erwin Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, 1998.
Reference Books
1. L. Ahlfors, Complex Analysis, McGraw-Hill International Edition, 1979.
2. R.V. Churchill, Complex Variables and Applications, 4th Edition, Mc Graw –Hill, 1948.
3. A.Mood, F.Graybill, and D.Boes, *Introduction to the Theory of Statistics*, Tata McGraw Hill (Third Edition) 2008.
4. George Grätzer, Lattice Theory: Foundation, Springer Basel AG, 2011.