Curriculum of M. Sc., Mathematics
After revision 2021-2022

DEPARTMENT OF MATHEMATICS
SCHOOL OF MATHEMATICAL SCIENCES
BHARATHIDASAN UNIVERSITY
TIRUCHIRAPPALLI - 620024

Bos 21 Jun 2021

DEPARTMENT OF MATHEMATICS

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M.Sc., PROGRAMME IN MATHEMATICS (CBCS)

(For the candidates to be admitted from the year 2021-2022 onwards)

Semester	Courses
I	5 Core Courses
II	3 Core Courses 1 Department Elective Course 1 Non-Major Elective Course 1 Value Added Course[1]
III	3 Core Courses 1 Department Elective Course 1 Non-Major Elective Course 1 Value Added Course [1]
IV	2 Core Courses 2 Department Elective Courses 1 Project

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[1] Optional

*CORE COURSES (CC).

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits	Prerequisite (Exposure)
21M01CC	Linear Algebra	4	2	0	5	Nil
21M02CC	Real Analysis I	4	2	0	5	Nil
21M03CC	Ordinary Differential Equations	4	2	0	5	Nil
21M04CC	Theory of Numbers	4	2	0	5	Nil
21M05CC	Graph Theory	4	2	0	5	Nil
21M06CC	Algebra I	4	2	0	5	Nil
21M07CC	Real Analysis II	4	2	0	5	21M02CC
21M08CC	Topology	4	2	0	5	21M02CC
21M09CC	Algebra II	4	2	0	5	21M01CC 21M06CC
21M10CC	Complex Analysis	4	2	0	5	21M02CC 21M07CC
21M11CC	Measure Theory and Integration	4	2	0	5	21M02CC 21M07CC
21M12CC	Functional Analysis	4	2	0	5	21M02CC 21M07CC 21M11CC
21M13CC	Differential Geometry	4	2	0	5	21M08CC
	Project Work	-	-	-	5	-

*DEPARTMENT ELECTIVE COURSES (DEC).

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits	Prerequisite (Exposure)
21M01DEC	Partial Differential Equations	3	2	0	4	21M03CC
21M02DEC	Integral Equation and Calculus of Variations	3	2	0	4	21M03CC
21M03DEC	Optimization Techniques	3	2	0	4	Nil
21M04DEC	Probability and Statistics	3	2	0	4	Nil
21M05DEC	Numerical Analysis	3	2	0	4	21M03CC
21M06DEC	Classical Dynamics	3	2	0	4	21M03CC
21M07DEC	Fluid Dynamics	3	2	0	4	Nil
21M08DEC	Operator Theory	3	2	0	4	21M12CC
21M09DEC	Integral Transforms	3	2	0	4	21M03CC
21M10DEC	Stochastic Process	3	2	0	4	Nil
21M11DEC	Coding Theory	3	2	0	4	Nil
21M12DEC	Fixed point Theory	3	2	0	4	21M02CC
21M13DEC	Discrete Dynamical System	3	2	0	4	Nil
21M14DEC	Algebraic Topology	3	2	0	4	21M08CC
21M15DEC	Discrete Mathematics	3	2	0	4	Nill
21M16DEC	Probability Theory	3	2	0	4	21M11CC
21M17DEC	Mathematical Statistics	3	2	0	4	21M07CC

*NON-MAJOR ELECTIVE COURSES (NMEC).

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits	Prerequisite
21M01UEC	Object Oriented Programming using C++	2	0	1	2	+2 level Mathematics
21M02UEC	Resource Management Techniques	2	1	0	2	Nil
21M03UEC	Mathematical Modeling	2	1	0	2	Nil
21M04UEC	Statistics	2	1	0	2	Nil
21M05UEC	General Intelligence	2	1	0	2	Nil

VALUE ADDED COURSES(VAC). [1]

Code	Title of the Course	Lecture Hours	Tutorial Hours	Practical Hours	Credits	Prerequisite
21M01VAC	Introduction to Latex	1	0	1	2	Nil
21M02VAC	Introduction to Sagemath	1	0	1	2	Nil
21M03VAC	Introduction to Python Programming	1	0	1	2	Nil
21M04VAC	Introduction to Matlab	1	0	1	2	Nil
21M05VAC	Sagemath for Abstract Algebra	1	0	1	2	Nil
21M06VAC	Introduction to R Programming	1	0	1	2	Nil
21M07VAC	Quantitative Aptitude	1	0	1	2	Nil

For each Course other than the Project.

Continuous Internal Assessment (CIA) - 25 Marks
End Semester Examination (ESE) - 75 Marks
Total - 100 Marks
ESE Duration - 3 Hours

Question paper pattern and CIA components.

10 questions compulsory	10×02	=	20 Marks	(2 from each unit)
5 questions	05×05	=	25 Marks	(either or, one from each unit)
3 questions from 5	03×10	=	30 Marks	(one question from each unit)
Total			75 Marks	

CIA components.

Tests - 15 Marks (2 tests from 3)
Seminar - 5 Marks
Assignment - 5 Marks

For Project Dissertation.

Evaluation (Internal examiner (40) and
external examiner (40)) - 80 Marks
Viva Voce - 20 Marks
Total - 100 Marks

Total credits should not be less than 90

[1]The marks of VAC are included in the fourth semester marks statement and not added in the CGPA

Programme Outcomes:

- PG Graduands are Professionally Competent with characteristic Knowledge- bank, Skill-set, Mind-set and Pragmatic Wisdom in their chosen fields.
- PG Graduands demonstrate the desired sense of being Seasoned and exhibit unequivocal Spiritedness with excellent qualities of productive contribution to society and nation in the arena Science and Technology.
- PG Graduands are mentored such that they exert Leadership Latitude in their chosen fields with commitment to novelty and distinction.
- PG Graduands are directed in understanding of ethical principles and responsibilities, moral and social values in day-to-day life thereby attaining Cultural and Civilized personality.
- PG Graduands are able to Collate information from different kinds of sources and gain a coherent understanding of the subject.

Programme Specific Outcomes:

- Mastery of Fundamental Mathematical Concepts (Algebra, Analysis, Geometry)
- Will gain the ability to understand and deal with abstract concepts
- Communicate mathematical concepts effectively
- Ability to think critically and creatively
- Analyze and model real world problems based on mathematical principles
- Ability to solve problems which are modeled
- Communicate the solutions in rigorous mathematical language
- Ability to progress independently and ethically

CORE COURSES

LINEAR ALGEBRA

Course Code: 21M01CC
Prerequisite: Nil

L	T	P	C
4	2	0	5

Objectives.

- Linear Algebra is ubiquitous in Mathematics and therefore a strong foundation has to be laid in studying the abstract algebraic concepts intertwining geometric ideas.
- The fundamental notions of vector spaces viz linear dependence, basis and dimension and linear transformations on these spaces have to be studied thoroughly.
- The students have to learn how the subject encompasses the isomorphic theory of matrices and comprehend the key ideas involved in the study of the structure theory of linear maps.

Unit-I. Vector spaces - Subspaces - Linear Combinations and Systems of Linear Equations - Linear Dependence and Linear Independence - Bases and Dimension - Maximal Linearly Independent Subsets.

Unit-II. Linear Transformations, Null Spaces, and Ranges - The Matrix Representation of a Linear Transformation - Combination of Linear Transformations and Matrix Multiplication - Invertibility and Isomorphisms - The Change of Coordinate Matrix.

Unit-III. Elementary Matrix Operations and Elementary Matrices - The Rank of a Matrix and Matrix Inverses - System of Linear Equations - Theoretical Aspects and Computational Aspects - Determinants of Order 2 - Determinants of Order n - Properties of Determinants - Summary - Important Facts about Determinants.

Unit-IV. Eigenvalues and Eigenvectors - Diagonalizability - Cayley Hamilton Theorem.

Unit-V. The Jordan Canonical Form 1 - The Jordan Canonical Form 2 - The Minimal polynomial.

Unit-VI (Advanced topics only for discussion).
Current Contours: Introduction to Module theory

Text book(s):
Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, Linear Algebra, Fourth Edition, PHI Learning Private Limited, New Delhi, 2014.

Unit-I: Chapters 1
Unit-II: Chapter 2: Sections 2.1 to 2.5
Unit-III: Chapter 3 and Chapter 4: Sections 4.1 to 4.4
Unit-IV: Chapter 5: Sections 5.1 to 5.3 and 5.5
Unit-V: Chapter 7 Sections 7.1 to 7.3

References.

(1) S. Kumaresan, Linear Algebra, Prentice-Hall of India Ltd, 2000.
(2) K. Hoffman and R. Kunze, Linear Algebra, Second Edition, Pearson, 2015.
(3) M.Artin, Algebra, Pearson, 2015.
(4) Jin Ho Kwak, Linear Algebra, Second Edition, Birkhäuser, 2004.
(5) I.N. Herstein, Topics in Algebra, Wiley India Pvt Limited, New Delhi, 2012.
(6) Gilbert Strang, Linear Algebra and its applications, Cengage Learning 8th Indian edt, 2011.
(7) A.R. Rao, P. Bhimashankaram, Linear Algebra, 2nd Edition, Hindustan Book Agency, 2000.
(8) V. Krishnamurthy et al, Introduction to Linear Algebra, East West Press Ltd, 1985.

Course Outcomes:

Students will be able to

- Realise that the subject evolves as a generalization of solving a system of linear equations.
- Discuss in detail the basic concepts of Linear dependence, basis and dimension of a vector space. The students will be able to demonstrate how the geometric ideas turns into rigorous proofs.
- Master the dimension formula and rank and nullity theorem which are often exploited.
- Capture the idea of producing lot of structure preserving maps (Linear transformations). Further the study of algebras of linear maps would be accomplished.
- Having got trained in numerous examples the student realizes the isomorphic theory of Linear transformations and matrices.
- Learn the theory of determinants and put them in practice.
- Understand that the central theme of structure theory of linear maps is to decompose the given vector space as a direct sum of generalized the eigenspaces using the given map on it.
- To find the Jordan canonical forms of various linear transformation and thereby able to solve various problems.
- Understand that linear Algebra plays a fundamental role in many areas of mathematics including Algebra, Geometry, Functional analysis and which finds widest application in Physics, Chemistry and elsewhere.

REAL ANALYSIS I

Course Code: 21M02CC
Prerequisite: Nil

L	T	P	C
4	2	0	5

Objectives.

- To learn the basic quantitative concepts of real analysis such as least upper bound property, convergence of sequences and continuity of functions.
- To comprehend the qualitative aspects of real analysis in the setting of Metric spaces. The intrinsic geometric ideas in the basic notions of metric spaces viz., open sets, closed sets, limit points, cluster points, connectedness and compactness have to be brought out.

Unit-I. Sets and Functions, Mathematical Induction, Finite and Infinite sets. Real Number system: Algebraic and Order properties: Infimum, Supremum, LUB Axiom. Countable and uncountable sets.

Unit-II. Metric spaces - Definition and examples - open balls and open sets

Unit-III. Sequences and Series of real numbers - limit theorems - monotone sequences - Cauchy criterion - limsup, liminf - Convergent sequences in metric spaces - limit and cluster points - Cauchy sequences - Bounded sets - Dense sets.

Unit-IV. Continuous functions - Equivalent Definitions of Continuity - Uniform Continuity -Limit of a function - Discontinuities of a Real Valued function - Compact spaces and their properties - Continuous functions on Compact spaces- Characterization of Compact Metric spaces.

Unit-V. Connectedness : Connected spaces - Complete metric spaces - Examples- Baire Category Theorem - Banach Contraction Principle.
Unit-VI (Advanced topics only for discussion).
Current Contours: Generalizations to topological spaces.

Text book(s):

(1) R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis 4th Edn, Wiley India Edition, 2014.
(2) S. Kumaresan, Topology of Metric Spaces, 2nd Edition, Narosa Publishing House, New Delhi, 2011.

Unit-I:	Chapters 1 and 2 from [1]
Unit-II:	Chapter 1 from [2]
Unit-III:	Chapter 3 from [1] and Chapter 2 sections 2.1 to 2.5 from [2]
Unit-IV:	Chapter 3, Chapter 4 from [2] (sections 3.3 and 3.6 omitted) and Chapter 5 from [1]
Unit-V:	Chapter 5 Section 5.1 and Chapter 6 sections 6.1, 6.3 and 6.4 (section 6.2, 6.3.16 and 6.3.17 omitted) from [2]

References.

(1) Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Third Indian Reprint, 2015.
(2) Edward D. Gaughan, Introduction to Analysis, AMS, Indian edition, 2010.
(3) Kenneth A. Ross, Elementary Analysis: The Theory of Calculus, Springer Verlag, 2004.
(4) M.H. Protter, C.B. Morrey, A First Course in Real Analysis, 2nd Edition, Springer Verlag, 2004.
(5) S.K. Berberian, A First course in Real Analysis, Springer Verlag, Reprint, 2019.
(6) Charles Chapman Pugh, Real Mathematical Analysis, Springer Verlag, 2017.
(7) R.P. Boas, A primer of real functions, Mathematical Association of America, 1966.
(8) Tom M. Apostol, Mathematical Analysis 2 edn, Narosa, New Delhi, Reprint, 2002.
(9) Walter Rudin, Principles of Mathematical Analysis,Third Edition, Mcgraw Hill, 2017.
(10) N.L. Carothers, Real Analysis, Cambridge University Press, South Asian Edition, 2006.

Course Outcomes:

Students will be able to

- Inculcate interest in analysis and understand how pictures and leading questions get into the strategy of proofs.
- Gain mastery in the fundamental concepts such as sets and functions, Induction principle, Finite and Infinite sets. In real number system they would get insight in algebraic and order properties in a top down approach.
- Appreciate the role of least upper bound property in real analysis which underlies all crucial results.
- Understand the basic concepts in metric spaces geometrically and with rigor.
- Realize the key idea convergence of sequences and the quantitative inequality estimates. Here numerous examples would have demonstrated the role of inequalities.
- Learn the crucial concept of continuity of functions and uniform continuity and will be able to work on problems emphasizing these ideas of real analysis.
- Study thoroughly the metric topology and discuss the ideas connecting compactness and continuity and connectedness and continuity.
- Utilize the Banach contraction principle in formulating and solving various important problems.

ORDINARY DIFFERENTIAL EQUATIONS

Course Code: 21M03CC
Prerequisite: Nil

L	T	P	C
4	2	0	5

Objectives.

- Ordinary differential equations arise as a natural mathematical model of many physical situations and hence the concepts involved in solving them are rudiments and vital for the course. The main objective is to give elementary, thorough, systematic approach for the subject.
- The existence and uniqueness of solutions for first order differential equations are studied in detail. Qualitative properties of solutions are carried out elaborately.

Unit-I. The general solution of the homogeneous equation - The use of one known solution to find another - The method of variation of parameters - Power Series solutions. A review of power series - Series solutions of first order equations - Second order linear equations; Ordinary points.

Unit-II. Regular Singular Points - Gauss's hypergeometric equation - The Point at infinity - Legendre Polynomials - Bessel functions - Properties of Legendre Polynomials and Bessel functions.

Unit-III. Linear Systems of First Order Equations - Homogeneous Equations with Constant Coefficients - The Existence and Uniqueness of Solutions of Initial Value Problem for First Order Ordinary Differential Equations - The Method of Solutions of Successive Approximations and Picard's Theorem.

Unit-IV. Oscillation Theory and Boundary value problems - Qualitative Properties of Solutions - Sturm Comparison Theorems - Eigenvalues, Eigenfunctions and the Vibrating String.

Unit-V. Nonlinear equations: Autonomous Systems; the phase plane and its phenomena - Types of critical points; Stability - critical points and stability for linear systems - Stability by Liapunov's direct method - Simple critical points of nonlinear systems.

Unit-VI (Advanced topics only for discussion).

Current Contours: System of ode and using Canonical forms to solve.

Text book(s):

G.F. Simmons, Differential Equations with Applications and Historical Notes, 2nd Edition, McGraw Hill, 2017.

Unit-I: Chapter 3: Sections 15, 16, 19 and Chapter 5: Sections 25 to 27
Unit-II: Chapter 5 : Sections 28 to 31 and Chapter 6: Sections 32 to 35
Unit-III: Chapter 7: Sections 37, 38 and Chapter 11: Sections 55, 56
Unit-IV: Chapter 4: Sections 22 to 24
Unit-V: Chapter 8: Sections 40 to 44

References.

(1) E.A. Coddington, Ordinary Differential Equaitons, McGraw Hill, 1989.
(2) M.E. Taylor, Introduction to Differential Equations, AMS Indian Edition, 2011.
(3) M. Braun, Differential Equations and Their Applications, 4th Edition, Springer, 1993.
(4) Boyce and DiPrima, Elementary Differential Equations and Boundary Value Problems, 9th Edn, John Wiley, 2009.
(5) S. Deo et al, A textbook of Differential Equations, McGraw Hill, 2002.
(6) Lawrence Perko, Differential Equations and Dynamical Systems, Springer, 2006.
(7) Tyn Myint-U, Ordinary Differential Equations, North-Holland, New York, 1978.

Course Outcomes:

Students will be able to

- Find the general solution of the first order linear homogeneous equations.
- Understand the utility of the theory of power series which is studied in Real Analysis course through solving various second order differential equations.
- Get introduced to the Hypergeometric functions which arises in connection with solutions of the second order ordinary differential equations with regular singular points.
- Solve the problems arises in Mathematical physics using properties of special functions.
- Understand the importance of studying well-posedness of the problem namely existence, uniqueness and continuous dependence of first order differential equations through Picard's theorem.
- Understand the utility of the concepts from linear algebra and analysis in the study of system of first order equations.
- Discuss the Qualitative properties of solutions of first and second order equations. Also they will be able to work on numerous problems using comparison theorem in Sturm Liouville problems.
- Learn the nature of solutions which involves critical points and phase portrait of non-linear equations.

THEORY OF NUMBERS

Course Code: 21M04CC
Prerequisite: Nil

L	T	P	C
4	2	0	5

Objectives.

- Number theory is one of the classical branches of Mathematics. In this course, the basic concepts such as divisibility, primes, congruences and solutions in congruences are introduced in detail. Emphasize is made on the concepts which turn out to be concrete examples which motivate the abstract ideas in the algebra course.
- Quadratic Residues, Mobius inversion Formula and the Diophantine equations and their solutions have to be introduced.

Unit-I. Introduction - Divisibility - Primes - The Binomial Theorem - Congruences Euler's totient - Fermat's, Euler's and Wilson's Theorems - Solutions of congruences - The Chinese Remainder theorem.

Unit-II. Prime power Moduli - Primitive roots and Power Residues - Number theory from an Algebraic Viewpoint - Groups, rings and fields.

Unit-III. Quadratic Residues - Quadratic Reciprocity - The Jacobi Symbol - Binary Quadratic Forms - Equivalence and Reduction of Binary Quadratic Forms - sum of two squares.

Unit-IV. Greatest integer Function - Arithmetic Functions - The Mobius Inversion Formula Recurrence Functions - Combinatorial number theory.

Unit-V. Diophantine Equations - The equation ax+by = c - Simultaneous Linear Diophantine Equations - Pythagorean Triangles - Assorted examples

Unit-VI (Advanced topics only for discussion).

Current Contours: A discussion on Prime number theorem

Text book(s):

Ivan Niven, Herbert S, Zuckerman and Hugh L, Montgomery, An Introduction to the Theory of Numbers, Fifth edn., John Wiley & Sons Inc, 2008.

Unit-I: Chapter 1 and Chapter 2 : Sections 2.1 to 2.3
Unit-II: Chapter 2 : Sections 2.6 to 2.11
Unit-III: Chapter 3: Sections 3.1 to 3.6
Unit-IV: Chapter 4
Unit-V: Chapter 5: Sections 5.1 to 5.4

References.

(1) Gareth A. Jones and J. Mary Jones, Elementary Number Theory, Springer Verlag, Indian Reprint, 2005.
(2) David M. Burton, Elementary Number Theory, 6th edition, McGraw Hill, 2007.
(3) George Andrews, Theory of Numbers, Saunders, 1971.
(4) William, Fundamentals of Number Theory, Leveque, Addison-Wesley Publishing Company, Phillipines, 1977.

Course Outcomes:

After completing this course, the student will be able to:

- Understand and work numerous problems on concepts of divisibility and primes.
- Gain expertise in Euler's totient, Fermat's, Euler's and Wilson's Theorems and work on applications illustrating them.
- Solve congruences as application of Chinese remainder Theorem.
- Understand number theory from algebraic point of view there by improving their sense of abstraction.
- Describe power residues and multiplicative groups.
- Discuss Quadratic residue and Jacobi symbol and work on sum of two squares problems.
- Attained mastery in the fundamentals of greatest integer function and recurrence functions and attacking combinatorial problems using them.
- Solve simple simultaneous linear Diophantine equations.

GRAPH THEORY

Course Code: 21M05CC
Prerequisite: Nil

L	T	P	C
4	2	0	5

Objectives.

- To train the students to get expertise in the mathematical concepts involved in the field of Graph theory which has applications in diverse areas including Computer science and Electrical Engineering.
- In this course, the rudiments of Graph theory viz., Paths and connectedness of Graphs, Matching, Planarity, Vertex colourings, Edge colourings, are introduced.

Unit-I. Graphs - Subgraphs - Isomorphism of graphs - Degrees of Vertices - Paths and Connectedness - Autumorphism of a Simple Graph - Operations on Graphs - Trees - Centers and Centroid.

Unit-II. Counting the Number of Spanning Trees - Cayley's Formula - Vertex Cuts and Edge Cuts - Connectivity and Edge-connectivity - Blocks - Cyclical Edge-connectivity of a Graph.

Unit-III. 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.

Unit-IV. Vertex Coloring - Chromatic Number - Critical Graphs - Brooks' Theorem - Girth - Triangle-Free Graphs - Mycielski's Construction - Edge Colorings of Graphs - Vizing's Theorem - Chromatic Polynomials.

Unit-V. Planar and Nonplanar Graphs - Euler's Formula and its Consequences - K5 and K3,3 are Nonplanar graphs - Dual of a Plane Graph - The Four Color Theorem and the Heawood Five-Color Theorem - Kuratowski's Theorem (without proof).

Unit-VI (Advanced topics only for discussion).

Current Contours: The Four Color Conjecture

Text book(s):

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

Unit-I: Chapter 1: 1.1-1.6, 1.8 and Chapter 3:3.1-3.5
Unit-II: Chapter 4:4.1-4.5
Unit-III: Chapter 5:5.1-5.5
Unit-IV: Chapter 7: 7.1,7.2,7.3.1, 7.5,7.6.2,7.9
Unit-V: Chapter 8: 8.1-8.7

References.

(1) Bondy J.A. and U.S.R. Murty, Graph Theory with Applications. North Holland, New York ,1976.
(2) Douglas B. West, Introduction to Graph Theory, Second Edition, PHI Learning Private Ltd, New Delhi-2011.

(3) G. Chartrand, Linda Lesniak and Ping Zhang, Graphs and Digraphs, Fifth Edition, CRC press, 2011.

Course Outcomes:

After completing this course, the student will be able to:

- Understand and work on the elementary concepts of graphs namely, subgraph, cut vertex, blocks.
- To understand and apply the fundamental concepts in graph theory.
- To apply graph theory based tools in solving practical problems.
- Define how graphs serve as models for many standard problems.
- Understand basic concepts in Trees and Discuss matching problems and its applications elsewhere.
- Workout in detail the connectivity of a given graph with help of Menger's theorem.
- Comprehend and work on the concepts of planarity and discuss the dual of a plane graph.
- Elucidate on the famous Four-Color theorem and discuss Tait Coloring.

ALGEBRA - I

Course Code: 21M06CC
Prerequisite: Nil

L	T	P	C
4	2	0	5

Objectives.

- To learn the fundamental abstract algebraic structures namely groups and rings with rigor. The need for the abstract concepts are illustrated with numerous examples.
- To comprehend how group action is effectively used in Sylow's theorems.
- To study in detail the basic concepts of Rings such as Ring homomorphisms and Euclidean domains.

Unit-I. Binary Operations - Groups - Subgroups - Permutations I - Permutations II - Cyclic Groups.

Unit-II. Isomorphisms - Direct Products - Finitely Generated Abelian groups - Groups of Cosets - Normal subgroups and factor groups- Homomorphisms.

Unit-III. Series of Groups - Isomorphism theorems- Proof of the Jordan Holder theorem—Group action on a set- Applications of G-sets to counting - Sylow's theorems - Applications of Sylow theorems.

Unit-IV. Rings - Integral Domains - Some non-commutative examples - The Field of quotients - Quotient rings and Ideal.

Unit-V. Homomorphism of Rings - Rings of polynomials - Factorization of Polynomials over a field - Euclidean domains- Gaussian integers and norms.

Unit-VI (Advanced topics only for discussion).

Current Contours: Classification of finite Groups - Commutative rings.

Text book(s):

John B. Fraleigh, A First course in Abstract Algebra, Pearson, 7th Edition, 2013.

Unit-I: Chapter 1, 2, 3,4,5,6
Unit-II: Chapter 7,8,9,11,12,13
Unit-III: Chapter 14,15,16,17,18,19
Unit-IV: Chapter 23,24,25,26,27,28
Unit-V: Chapter 29,30,31,33,34

References.

(1) Gallian, Contemporary Abstract Algebra, Cenpage Learning India Pvt Ltd., Ninth Edition, 2019.
(2) Mark R. Sepanski, Algebra, AMS Indian Edition, 2012.
(3) David S. Dummit and Richard M. Foote, Abstract Algebra, Wiley , Third Edition, 2011.
(4) P.B. Bhattacharya et al., Basic Abstract Algebra, 2nd edition, Cambridge University Press, 2003.
(5) C. Lanski, Concepts in Abstract Algebra, AMS Indian edition, 2010
(6) M.Artin, Algebra, Pearson Education India, New Delhi, 2015.
(7) I.N.Herstein, Topics in Algebra, John Wiley, 2nd Edition, 2006.

(8) R. Solomon, Abstract Algebra, AMS Indian edition, 2010.

Course Outcomes:

After completing this course, the student will be able to:

- Gain expertise in the basic concepts of group theory with the help of numerous examples.
- Discuss in detail about permutation groups and Normal subgroups and discuss on counting tricks in algebra.
- Illustrate Jordan holder theorem with examples.
- Bring out the key steps involved in proving Sylow theorems.
- Use Sylow's theorems to classify groups of finite order upto 120.
- Understand how the number theoretic concepts of the integers serve as a motivation for the algebraic concepts for Rings.
- Learn how to obtain the Field of Quotients of an integral domain.
- Identify various forms of Polynomial rings. Further they will be able to discuss about Euclidean domains.

REAL ANALYSIS II

Course Code: 21M07CC
Prerequisite: 21M02CC

L	T	P	C
4	2	0	5

Objectives.

- To perceive and retain that the basic idea of differential calculus is to approximate the given function by a first degree polynomial. To study the powerful tool of maxima-minima in calculus using mean value theorems.
- To study the concept of convergence of sequences and series of functions and to introduce the theory of multivariable calculus

Unit-I. Differentiation of single variable: Derivatives - The chain rule - local extrema - Rolle's theorem - Mean Value Theorem - Taylor's formula - Derivatives of vector - valued functions - Functions of Bounded variation and rectifiable curves - Total variation - Functions of bounded variation - Equivalence of paths - Change of parameter.

Unit-II. Riemann-Stieltjes integral: Definition - linear properties of the integral - Necessary conditions for the existence - First fundamental theorem of Integral calculus - Mean Value Theorems for integrals - Second fundamental theorem of Integral calculus- Change of variable in a Riemann integral - Second Mean value Theorem for Riemann integrals

Unit-III. Sequence and series of functions - Point wise convergence - Uniform convergence - Uniform convergence and integration - Uniform convergence and Differentiation - Sufficient conditions for uniform convergence of a series - The Weierstrass theorem - Equicontinuity - The Stone - Weierstrass theorem.

Unit-IV. Functions of Severable variables - Directional derivative - Total derivative - Jacobian - Chain rule - Mean Value Theorem - Taylor's formula.

Unit-V. Inverse function theorem - Implicit function theorem - Extremum problems with side conditions.

Unit-VI (Advanced topics only for discussion).

Current Contours: Calculus on Manifolds.

Text book(s):

(1) Tom M. Apostol, Mathematical Analysis Second Edition, Narosa Publishing House, New Delhi, 1985.

(2) N.L. Carothers, Real Analysis, Cambridge University Press, South Asian Edition, 2000.

Unit-I:	Chapter 5 and 6 from (1)
Unit-II:	Chapter 7 Section 7.1 -7.22 from (1)
Unit-III:	Chapter 9 Section 9.1 - 9.11 and 9.14 -9.18 from (1)
	Chapter 11 and 12 from (2) (only the corresponding sections)
Unit-IV:	Chapter 12 from (1)
Unit-V:	Chapter 13 from (1)

References.

(1) Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Third Indian Reprint, 2015.
(2) M.H. Protter, C.B. Morrey, A First Course in Real Analysis, 2nd Edition, Springer Verlag International Edition, 1991.
(3) Tom Apostol, Calculas II, Wiley,2nd edition, 2007.
(4) Torrence Tao, Mathematical Analysis, Vol I & II, Hindustan Book Agency, 2006.
(5) J.E. Marsden, A.J. Tromba, A.Weinstein, Basic multivariable calculus, W.H.Freeman and Co Ltd, 2001.
(6) Robert T. Seeley, Calculas of Several Variables, Scott, Foresman and Co, 1970.
(7) T.W. Korner, A Companion to Analysis, AMS Indian edition, 2011.
(8) S. Kumaresan, A Course in Differential Geometry and Lie groups, Hindustan Book Agency, 2002.
(9) Walter Rudin, Principles of Mathematical Analysis,Third Edition, Mcgraw Hill, 2017.

Course Outcomes:

After completing this course, the student will be able to:

- Gain mastery on single variable differentiable calculus. The role of Mean Value of theorem will be appreciated.
- Discuss about functions of bounded variations and rectifiable paths.
- Comprehend the basic integration theory and demonstrate how the results are obtained and gain the confidence in Analysis.
- Attain the mastery in the concept of convergence of sequences and series of functions. Students will be able to identify and discuss about them occuring in lot of examples and get geometric insights from them.
- Get solid foundation on the fundamentals of multivariable calculas. The key idea of perceiving derivative as a linear map will be well understood with demonstrations.
- Calculate Directional derivative and Total derivative of functions and discuss about Jacobian matrix. Further they able to deal with chain rule and the Mean Value Theorem of Multivariable Calculus exploiting the trick of one variable calculas.
- Thoroughly understand the geometric ideas leading to implicit and inverse function theorems.
- Use of Lagrange multiplier trick to solve extremum problems.

TOPOLOGY

Course Code: 21M08CC
Prerequisite: 21M02CC

L	T	P	C
4	2	0	5

Objectives.

- To introduce the notion of topological spaces and to characterize the properties of convergence, continuity of functions, compactness and connectedness of the spaces. Emphasize is to bring out the intrinsic geometric ideas in the concepts.
- To lay strong foundation on obtaining weak topology induced by maps and to study product topology as a special case.
- To study in depth the ingenious idea of the construction of the continuous real valued functions on normal spaces.

Unit-I. TOPOLOGICAL SPACES : Topological spaces - Basis for a topology - The order topology - The product topology on $X \times Y$ - The subspace topology - Closed sets and limit points.

Unit-II. CONTINUOUS FUNCTIONS : Continuous functions - the product topology - The metric topology.

Unit-III. CONNECTEDNESS: Connected spaces - connected subspaces of the Real line - Components and local connectedness.

Unit-IV. COMPACTNESS: Compact spaces - compact subspaces of the Real line - Arzela - Ascoli theorem -Limit Point Compactness - Local Compactness -Tychonoff's Theorem.

Unit-V. COUNTABILITY AND SEPARATION AXIOMS: The Countability Axioms - The separation Axioms - Normal spaces - The Urysohn Lemma - The Urysohn metrization Theorem - The Tietze extension theorem.

Unit-VI (Advanced topics only for discussion).

Current Contours: Elementary concepts from Algebraic topology.

Text book(s):

James R. Munkres, Topology (2nd Edition) Pearson Education Pvt. Ltd., New Delhi-2002 (Third Indian Reprint)

Unit-I: Chapter 2: Sections 12 to 17
Unit-II: Chapter 2: Sections 18 to 21 (Omit Section 22)
Unit-III: Chapter 3: Sections 23 to 25.
Unit-IV: Chapter 3: Sections 26 to 29 and Chapter 5: Section 37
Unit-V: Chapter 4: Sections 30 to 35.

References.

(1) M.A. Armstong, Basic Topology, Springer Verlag, 2005
(2) J. Dugundji, Topology, Prentice Hall of India, New Delhi, 1975.
(3) K.D. Joshi, Introduction to General Topology,New Age International Private Limited, 2017.
(4) O. Ya. Viro, Elementry Topology: Problem Textbook, AMS Indian Edition, 2012.

(5) J.L. Kelly, General Topology, Dover Publications Inc., 2017

(6) L.Steen and J.Seebach, Counterexamples in Topology, Holt, Rinehart and Winston,Dover Publications Inc., 1995..

(7) G.F.Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2017.

Course Outcomes:

After completing this course, the student will be able to:

- Realize how topological spaces and the basic notions of it are generalization of metric spaces.
- Identify and characterize convergence of sequences, which sets are closed, compact and connected in lots of examples.
- Explore the continuity of functions in various topological spaces.
- Elucidate the difference in the concept of base for a given topology and base generating some topology.
- Understand generating topologies and product topology as a particular case of it.
- Demonstrate universal mapping properties in all the three cases viz product topology, weak topology and quotient topology.
- Prove all the topological properties involved in counting and separation axioms with the help of pictures.
- Explain the proof of Tietze extension theorem in detail.

ALGEBRA - II

Course Code: 21M09CC
Prerequisite: 21M01CC, 21M06CC

L	T	P	C
4	2	0	5

Objectives.

- To gain expertise in basic ring theory
- To introduce Galois theory and obtain the fundamental Galois correspondence.

Unit-I. Prime ideals and Maximal Ideals, Irreducible polynomials.

Unit-II. Classical Formulas, Splitting Fields.

Unit-III. The Galois Group, Roots of Unity, Solvability by Radicals.

Unit-IV. Independence of Characters, Galois Extensions.

Unit-V. The Fundamental theorem of Galois theory, Applications, Galois Great Theorem.
Unit-VI (Advanced topics only for discussion).
Current Contours: Elementary concepts from commutative algebra. Applications of field theory to coding theory.
Text book(s):
Joseph Rotman, Galois Theory, 2nd edition, Springer Verlag, 2001.

Unit-I:	Pages 31 - 43
Unit-II:	Pages 44 - 58
Unit-III:	Pages 59 - 75
Unit-IV:	Pages 76 - 82
Unit-V:	Pages 83 - 95

References.

(1) David S. Dummit and Richard M. Foote, Abstract Algebra, Wiley , Third Edition, 2011.
(2) Serge Lang. Algebra - Revised third edition - Springer - Verlag - 2005.
(3) Ian Stewart, Galois Theory,Chapman and Hall/CRC,Fourth edition 2015.
(4) R. Solomon, Abstract Algebra, AMS Indian edition, 2010.
(5) C. Lanski, Concepts in Abstract Algebra, AMS Indian edition, 2010
(6) John B. Fraleigh, A First course in Abstract Algebra, Pearson, 7th Edition, 2013.
(7) M.Artin, Algebra,Pearson Education India, New Delhi, 2015.
(8) I.N.Herstein, Topics in Algebra, John Wiley, 2nd Edition, 2006.

Course Outcomes:
After completing this course, the student will be able to:

- Understand the important concepts of prime ideal and maximal ideal and identify them in various examples.
- Explain in detail the notions principal ideal domain and unique factorization domains and their connections with Euclidean domain.
- Learn the fundamental concept in field theory of field extensions and would see the idea of generating new fields.
- Workout the dimensions of various extension fields using tower law.

- Have clear cut idea in the notions of Galois groups, normal extensions and separable extensions and illustrate them with various examples.
- Understand the proof of solvability by Radicals. Students will be able to prove the impossibility of certain geometric constructions.
- Learn Galois correspondance and give a proof of fundamental theorem of algebra.
- Able to understand the Fundamental theorem of Galois theory.

COMPLEX ANALYSIS

Course Code: 21M10CC
Prerequisite: 21M02CC, 21M07CC

L	T	P	C
4	2	0	5

Objectives.

- To give a careful treatment of argument and logarithms and winding numbers
- To introduce analytic functions which are locally a power series and to study the profound Cauchy theory which says analytic functions are complex differentiable (holomorphic) functions on an open set.
- To emphasize that the subject is a amalgamation of ideas from analysis, geometry and topology

Unit-I. Power Series - Uniform Convergence and Continuity - Arguments on $\mathbb{C}^*$- Logarithms - Power Series and Analytic Functions-Cauchy-Riemann Equations - Rest of the sections from chapter 1 to chapter 5 are for self study.

Unit-II. Complex Integration:Integration of functions from $\mathbb{R}$ to $\mathbb{C}$ - Path Integrals - ML-inequality - A Preview of Cauchy Theory - Cauchy Theory: Cauchy's Theorem for Star-Shaped Domains - Applications of Cauchy's Theorem - An Extension of Cauchy's Theorem - Green's Theorem and Cauchy's Theorem.

Unit-III. Cauchy Integral Formula:Cauchy Integral Formula - Mean Value Property - Liouville's Theorem - Morera's Theorem - Identity Theorem - Maximum Modulus Theorem

Unit-IV. Isolated Singularities and Laurent Series:Isolated Singularities - Laurent Series - Characterization of Singularities - Meromorphic Functions - Winding Numbers of Closed Curves: Winding Numbers -I - Residue Theorem and its Applications: Residue Theorem - Arugument Principle.

Unit-V. Extended Complex Plane:Point at Infinity - Fractional Linear Transformations - Functions on the Extended Plane - Real Integrals: Improper Integrals - Evaluation of Real Integrals - Summation of Infinite Series

Unit-VI (Advanced topics only for discussion). Analytic Continuation - Global version of Cauchy's theorem

Text book(s): S.Kumaresan, A Pathway to Complex Analysis, Techno world Publications, 2021.

Unit-I:	Chapter 1 - Chapter 5: Emphasis on Sections 2.3, 3.2, 4.3, 4.4, 5.5 and 5.6 Rest of the sections from Chapters 1-5 are for self study.
Unit-II:	Chapters 6 and 7.
Unit-III:	Chapter 8
Unit-IV:	Chapters 9,10 and 11. On Chapter 10 only Section 10.1 is included.
Unit-V:	Chapters 13: 13.1 - 13.3 and Chapter 15
Unit-VI:	Chapter 16 and 18.

References.

(1) Bak, J., Newman and D.J, Complex Analysis, 3rd edition, Springer Nature, New York, 2015.
(2) R. Priestely, Introduction to Complex Analysis, Oxford India, 2008.
(3) Theodore W. Gamelin, Complex Analysis, Springer Verlag, 2003.
(4) Lars V. Ahlfors, Complex Analysis, Third Ed. McGraw-Hill Book Company, Tokyo, 2017.
(5) R.V. Churchill & J.W. Brown, Complex Variables and applications, 8th edition, McGraw-Hill, 2017.
(6) L.S. Hahn and B. Epstein, Classical Complex analysis, Jones and Barlett Student Edition, 2011.
(7) J.B. Conway, Functions of One Complex Variable, Narosa, 2 edn., 2000.
(8) S. Ponnusamy and H. Silverman, Complex Variables with applications, Birkhauser, 2006.
(9) Donald Sarason, Notes on Complex Function theory, Hindustan Book Agency, 1994.
(10) V. Karunakaran, Complex Analysis 2 edn, Narosa, New Delhi, 2005.

Course Outcomes:

After completing this course, the student will be able to:

- Understand the complex number system from geometric view point. Will gain mastery in arguments on $\mathbb{C}^*$ and logarithms.
- Get expertise in the concept of convergence of sequences and series of complex numbers, continuity and differentiability of function on complex numbers. Also the students will be able to thoroughly understand and know the importance of power series in complex analysis.
- Workout the path integrals on the complex plane.
- Understand the central theme of Cauchy theory, viz., existence of local primitives and local power series expansion.
- Get acquainted with various techniques of proving fundamental theorem of algebra, open mapping theorem, maximum modulus theorem and Liouville/s theorem.
- Classify singularities, compute poles and residues and understand the Laurent series expansion.
- Appreciate and work on the topology of extended complex plane.
- Appreciate how topological ideas of the homotopy theory is used for proving the homotopy version of Cauchy theorem.

MEASURE THEORY AND INTEGRATION

Course Code: 21M11CC
Prerequisite: 21M02CC, 21M07CC

L	T	P	C
4	2	0	5

Objectives.

- To provide a concrete setting of Lebesgue measure and Lebesgue integral via the classical concepts of Jordan measure and the Riemann integration.
- To give an expert and thorough study on abstract measuresa and the modern integation theory including the standard convergence theorems.
- To introduce product measure and study the Fubini's theorem.

Unit-I. Measure on $\mathbb{R}$: - outer measure - measurable sets - Regularity- abstract Measures - elementary properties of abstract measures.

Unit-II. Integration of positive functions - Integration of complex functions - The role played by sets of measure zero.

Unit-III. Measurability on cartesian products - Product Measure- The Fubini's theorem - Completion of Product measures- convolutions.

Unit-IV. L^p spaces: - convex function and inqualities - completeness of L^p spaces .

Unit-V. Signed Measures - Hahn Decomposition - Jordan Decomposition - Radon Nikodym theorem.

Unit-VI (Advanced topics only for discussion).

Current Contours: Riesz- Markov Kakutani Theorem

Text book(s):

(1) G. de Barra, Measure Theory And Integration, NewAge International Pvt.Ltd, 2013.
(2) W. Rudin, Real and Complex Analysis 3edn, McGraw-Hill, 2017.

Unit-I:	Chapter 2 - Section 2.1 to2.3 from [1] and Chapter 1 - pages 5 -19 (till the end of 1.22) from [2].
Unit-II:	Chapter 1 - pages 19 -31 from [2].
Unit-III:	Chapter 8 - pages 160-172 from [2].
Unit-IV:	Chapter 3 - pages 62 -70 from [2].
Unit-V:	Chapter 8 Sections 8.1 -8.3 from [1].

References.

(1) J R.G. Bartle, Elements of Integration and Lebesgue measure, Wiley India Ltd, 2014.
(2) C.D. Aliprantis and O.Burkinshaw, Priniciples of Real Analysis 3rd edn, Academic Press, Inc. New York, 1998.
(3) I.K.Rana, An Introduction to Measure and Integration, 2edn ,Narosa Publishing House, NewDelhi, 2007.
(4) H.L.Royden, Real Analysis, Pearson, Third edition, 2015.
(5) R.G. Bartle, Modern theory of integration, AMS, 2000.

Course Outcomes:

After completing this course, the student will be able to:

- Appreciate the power of Riemann integration and its drawbacks. They will be able to capture the need for the modern integration theory.
- Understand the concept of Caratheodory construction of a measure from an outer measure in the concrete cases.
- Discuss the concept of sigma algebra and their examples. Student will be able to understand the set of all Lebesque measurable set is a sigma algebra.
- Observe that the idea of measurable function, simple functions and their properties.
- Discuss about the importance of monotone convergence theorem, dominated convergence theorem and Fauto's lemma.
- Prove the completeness of Lp spaces.
- Understand the proof and apply Fubini's theorem in various cases.
- Comprehend the idea of Hahn and Jordan decomposition and Radon nikodym theorems.

FUNCTIONAL ANALYSIS

Course Code: 21M12CC
Prerequisite: 21M02CC, 21M07CC,21M11CC

L	T	P	C
4	2	0	5

Objectives.

- The idea behind the course is to emphasize very basic results which are needed for analysts and to give typical applications.
- To study normed linear spaces, four pillars of functional analysis, weak topologies and duality, Hilbert space theory and algebra of bounded linear operators.

Unit-I. Normed Linear Spaces - Examples - Normed Linear Spaces as Metric Spaces - Banach spaces - Hilbert Spaces - Bounded Linear Maps.

Unit-II. Riesz Representation Theorem for Hilbert Spaces - Finite Dimensional Spaces - Locally Compact Normed Linear Spaces - Quotient Spaces.

Unit-III. Five Pillars of Functional Analysis: Hahn-Banach Theorem - Open Mapping Theorem - Bounded Inverse Theorem - Closed Graph Theorem - Uniform Boundedness Principle.

Unit-IV. General Results on Compact Operators - Compact self-adjoint operators on Hilbert spaces - Dual spaces - Adjoint operators - Hilert space adjoint.

Unit-V. Banach Algebras - Spectrum of an element in a Banach Algebra - Spectrum of some standard operators - Finite Dimensional spectral theorem.

Unit-VI (Advanced topics only for discussion). Generating topologies - Weak and Weak* Topologies - Banach-Alaoglu Theorem.

Text book(s):

S.Kumaresan and D.Sukumar, Functional Analysis A first course, Narosa Publishing House, 2020.

Unit-I: Chapter 1: 1.1-1.5.
Unit-II: Chapter 1: 1.6-1.9.
Unit-III: Chapter 2 except 2.5.1,2.6.1.4 & 2.6.1.5.
Unit-IV: Chapter 3:3.1 & 3.4 and Chapter: 4.1-4.3.
Unit-V: Chapter 5 and Chapter 6: 6.1.
Unit-VI: Chapter 7.

References.

(1) B. Bollobas, Linear Analysis an introductory course, 2nd edn, Cambridge Mathematical Texts, Cambridge University Press, 1999.
(2) B.V. Limaye, Functional Analysis, Revised 3rd edn, New Age International, 2014.
(3) C. Goffman and G. Pedrick, A First Course in Functional Analysis, AMS, Chelesea, 2017
(4) B. Rynne and M.A. Youngson, Linear Functional Analyis, Springer UMS, 2008
(5) E. Kreyszig, Introductory Functional Analysis with applications, John Wiley, 2007.
(6) S. Kesavan, Functional Analysis, Hindustan book agency, 2014.
(7) G.F.Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2017.

(8) M.Thamban Nair, Functional Analysis: A first course, Prentice Hall of India, 2002.
(9) K. Yosida, Functional Analysis, Springer-Verlag, 1995.

Course Outcomes:

After completing this course, the student will be able to:

- Understand functional analytic language required to study problems of practical interest.
- Prove that all norms on a finite dimensional space are equivalent.
- Realize an important characterization: A normed linear space is locally compact if and only if it is finite dimensional.
- Comprehend the important of five pillars of functional analysis namely Hahn- Banach theorems, open mapping theorem, bounded inverse theorem, closed graph theorem and uniform boundedness principle.
- Gain mastery in basic Hilbert space theory: Projection theorem and Riesz representation theorem.
- Understand and gain mastery in compact operators
- Get a working knowledge on algebra of bounded linear operator.
- Study in detail the spectral properties of bounded linear operators.

DIFFERENTIAL GEOMETRY

Course Code: 21M13CC
Prerequisite: 21M08CC

L	T	P	C
4	2	0	5

Objectives.

- To introduce the geometry of n-dimensional oriented surfaces on Euclidean spaces using calculus of vector fields as a tool.
- To study geodesics, parallel transport, curvature and convexity of surfaces.

Unit-I. Graphs and Level sets - Vector fields - Tangent space.

Unit-II. Surfaces - Vector fields on surfaces

Unit-III. Gauss map - geodesics

Unit-IV. Parallel Transport - Weingarten map

Unit-V. Curvature of plane curves - arc length and Line integrals - Curvature of surfaces

Unit-VI (Advanced topics only for discussion).

Current Contours: Elementary concepts from commutative algebra. Applications of field theory to coding theory. The Gauss Bonet theorems.

Text book(s): J.A.Thorpe, Elementary topics in Differential geometry, UTM, Springer-Verlag, 4th reprint, 1994.

Unit-I: Chapters 1 to 3.
Unit-II: Chapters 4 and 5.
Unit-III: Chapters 6 and 7.
Unit-IV: Chapters 8 and 9.
Unit-V: Chapters 10 to 12.

References.

(1) S. Kumaresan, A Course in Differential Geometry, Hindustan Book Agency, 2002.
(2) Struik, D.T. Lectures on Classical Differential Geometry, Dover, 2003.
(3) Kobayashi S. and Nomizu. K. Foundations of Differential Geometry, Wiley Interscience Publishers, 1993.
(4) Wihelm Klingenberg: A course in Differential Geometry, Graduate Texts in Mathematics, Springer Verlag, 1978.
(5) T.J. Willmore, An Introduction to Differential Geometry, Dover, 2012.

Course Outcomes:

After completing this course, the student will be able to:

- Have a solid understanding of the subjects, linear algebra, mutivariable calculus and differential equations and a basic knowledge of theoretical physics.
- Sketch and workout graphs,level sets, tangent space and surfaces of given smooth maps.
- Good knowledge on calculus of vector fields.
- Understand how Gauss map helps to identify the surfaces that are mapped onto the unit n-sphere.
- Describe surfaces as a solution sets of differential equations.

- Exhibit geodesics on surfaces.
- Learn how parametrizations of plane curves can be used to evaluate integrals over the curve.
- Compute the Gaussian curvature of various surfaces.

DEPARTMENT ELECTIVE COURSES

PARTIAL DIFFERENTIAL EQUATIONS

Course Code: 21M01DEC
Prerequisite: 21M03CC

L	T	P	C
4	2	0	5

Objectives.

- The problem arising in physical phenomena widely involve partial differential equations (PDEs). The main objective is to equip students to classify partial differential equations and solve linear Partial Differential equations using different methods.
- To give a detailed study of Heat equation, Wave equation and Laplace equation.

Unit-I. First Order P.D.E. - Curves and Surfaces - Genesis of First Order P.D.E. - Classification of Integrals - Linear Equations of the First Order - Pfaffian Differential Equations - Compatible Systems - Charpit's Method - Jacobi's Method.

Unit-II. ntegral Surfaces Through a Given Curve - Quasi-Linear Equations - Non-linear First Order P.D.E.

Unit-III. econd Order P.D.E.: Genesis of Second Order P.D.E. - Classification of Second Order P.D.E. One-Dimensional Wave Equation - Vibrations of an Infinite String - Vibrations of a Semi-infinite String - Vibrations of a String of Finite Length (Method of separation of variables).

Unit-IV. Laplace's Equation: Boundary Value Problems - Maximum and Minimum Principles - The Cauchy Problem - The Dirichlet Problem for the Upper Half Plane - The Neumann Problem for the Upper Half Plane - The Dirichlet Interior Problem for a Circle - The Dirichlet Exterior Problem for a Circle - The Neumann Problem for a Circle - The Dirichlet Problem for a Rectangle - Harnack's Theorem .

Unit-V. Heat Conduction Problem - Heat Conduction - Infinite Rod Case - Heat Conduction Finite Rod Case - Duhamel's Principle - Wave Equation - Heat Conduction Equation.

Unit-VI (Advanced topics only for discussion).

Current Contours: Greens function - Theory of distributions.

Text book(s):

T.Amarnath, An Elementary Course in Partial Differential Equations, 2nd edn, Narosa Publishing Company, 2010.

Unit-I: Chapter 1: Sections 1.1 to 1.8
Unit-II: Chapter 1: Sections 1.9 to 1.11
Unit-III: Chapter 2: Sections 2.1 to 2.3.5, except 2.3.4
Unit-IV: Chapter 2: Sections 2.4.1 to 2.4.10
Unit-V: Chapter 2: Sections 2.4.11 to 2.6.2

References.

(1) Tyn Myint-U, Lokenath Debnath, Linear Partial Differential equations for scientists and engineers, 3rd edn, Birkhauser, 2007 .
(2) I.N. Snedden, Elements of Partial Differential Equations, Dover, 2006.
(3) F. Treves, Basic Linear Partial Differential Equations, Dover, 2006.
(4) A.K. Nandakumaran and P.S. Datti, Partial Differential Equations, Classical Theory with a Modern Touch, Cambridge University Press, 2020.
(5) K.S. Rao, Introduction to Partial Differential Equations, Prentice Hall of India, 2011.
(6) I.C. Evans, Partial Differential Equations, Orient Blackswan, 2014.
(7) F. John, Partial Differential Equations, Springer Verlag, 1991.
(8) Phoolan Prasad and Renuka Ravindran, Partial Differential Equations, New Age International, 2011.

Course Outcomes:

After completing this course, the student will be able to:

- Classify first order partial differential equations and their solutions.
- Solve first order equations and nonlinear partial differential equations using various methods.
- Use the method of characteristics to solve first order partial differential equations.
- Identify and solve the three main classes of second order equations, elliptic, parabolic and hyperbolic.
- Solve one dimensional wave equations using method of separation of variables.
- Classify the boundary value problems and analyse its solutions.
- Solve Heat conduction problem using Fourier series and cosines.
- Illustrate the use of pde in problems from Engineering and Biological Sciences.

INTEGRAL EQUATIONS AND CALCULUS OF VARIATIONS

Course Code: 21M02DEC
Prerequisite : 21M03CC

L	T	P	C
3	2	0	4

Objectives.

- To obtain thorough analysis of various aspects of calculus of variations.
- To acquire the knowledge of solving problems in the fields of mechanics and mathematical physics.

Calculus of variations.

Unit-I. Problems with fixed boundaries.

Unit-II. Problems with moving boundaries - Extremals with corners - One sided variations.

Unit-III. Sufficient conditions for Extremum - Conditional Extremum Problems.

Integral Equations.

Unit-IV. Linear Integral Equations - Definition, Regularity conditions - special kind of kernels - eigen values and eigen functions - convolution Integral - the inner and scalar product of two functions - Notation - reduction to a system of Algebraic equations - examples - Fredholm alternative - examples - an approximate method.

Unit-V. Method of successive approximations: Iterative scheme - examples - Volterra Integral equation - examples - some results about the resolvent kernel. Classical Fredholm Theory: the method of solution of Fredholm - Fredholm's first theorem - second theorem - third theorem.
Unit-VI (Advanced topics only for discussion).
Current Contours: Variational problems in fluid flow and Heat transfer.
Text book(s):

(1) Ram.P.Kanwal - Linear Integral Equations Theory and Practice,Birkhäuser, 2012.
(2) L. Elsgolts, Differential equations and the calculus of variations, University Press of the Pacific, 2003.

Unit-I:	Chapter 6 of [2]
Unit-II:	Chapter 7,8 of [2]
Unit-III:	Chapter 9,10 of [2]
Unit-IV:	Chapters 1 and 2 of [1]
Unit-V:	Chapters 3 and 4 of [1]

References.

(1) S.J. Mikhlin, Linear Integral Equations (translated from Russian), Hindustan Book Agency, 1960.
(2) I.N. Snedden, Mixed Boundary Value Problems in Potential Theory, North Holland, 1966.

Course Outcomes:

Students will be able to:

- Understand the concepts of variation and its properties.
- Use Euler's equation to solve various types of variational problems with fixed boundaries.
- Modify the Euler's formula for a class of curves with moving boundary points.
- Solve problems related with reflection and refraction, diffraction of light rays.
- Derive sufficient conditions based on second variation.
- Classify Fredholm , Volterra and singular type integral equations.
- Solve integral equations using Fredholm theorem, Fredholm Alternative theorem and method of successive approximations.
- Understand the classical Fredholm theory.

OPTIMIZATION TECHNIQUES

Course Code: 21M03DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To provide the insights into structures and processors that operations research can offer and the enormous practical utility of its various techniques.
- To explain the concepts and simultaneously to develop an understanding of problem solving methods based upon model formulation, solution procedures and analysis.

Unit-I. Linear Programming Problem - Simplex method - Integer Programming - Gomory's all I.P.P method - Fractional Cut Method - All integer L.P.P - Mixed integer L.P.P- Branch and Bound method.

Unit-II. Dynamic Programming - The recursive equation approach- Solution of discrete D.P.P - Some applications- Solutions of L.P.P by Dynamic Programming.

Unit-III. Queueing system - Deterministic Queueing Systems - Probability distributions in Queueing systems - Classification of Queueing Models - Transient and Steady States - Poisson Queueing Systems - Non-Poisson Queueing systems - Cost Models in Queueing - Other Queueing Models - Queueing Constrol - Queueing Theory and inventory Control.

Unit-IV. Inventory models - the concept of EOQ - deterministic inventory problems- with no shortages, with shortages - problems of EOQ with price breaks - Inventory problems with uncertain demands - One period problem - One period problem - without set-up cost , with set-up cost.

Unit-V. Non-Linear Programming - Formulation - constrained optimization - with equaling constraints, with in-equaling constraints - saddle point problems - Methods - Graphical sign - kuhn - Tucker conditions with non- negative constrains - quadratic programming- wolfe's modified simplex method - Beale's method - separable convex programming.

Unit-VI (Advanced topics only for discussion).

Current Contours: Geometric Programming -Goal Programming.

Text book(s):

Kanti Swarup, P . K. Gupta, Man Mohan, Operations Research, Sultan Chand & sons, New Delhi, 2019.

Unit-I: Sections 4.1 to 4.4, 7.1 - 7.7
Unit-II: Sections 13.1 to 13.7
Unit-III: Sections 21.1 to 21.14
Unit-IV: Sections 19.1 to 19.12, 20.4 - 20.6
Unit-V: Sections 27.1 - 27.7, 28.1 - 28.8.

References.

(1) Hamdy A. Taha, Operations Research (10th Edn.), McGraw Hill Publications, New Delhi.2019.

(2) Bazaara, Jarvis and Sherali, Linear Programming and Network Flows, 4th ed., John Wiley, 2010

(3) O.L. Mangasarian, Non Linear Programming, McGraw Hill, New York, 1994.

(4) Mokther S. Bazaraa and C.M. Shetty, Non Linear Programming, Theory and Algorithms, 3rd edn, Willy, New York, 2013.

(5) Prem Kumar Gupta and D.S. Hira, Operations Research : An Introduction, S. Chand and Co., Ltd. New Delhi, 2014.

(6) S.S. Rao, Optimization Theory and Applications, 4th edn, Wiley, 2009.

(7) G. Hadley, Linear Programming, Narosa Publishing House, 2002

Course Outcomes:

Students will be able to:

- Do mathematical formulation of a real life problem into a linear programming problem.
- Solve linear programming problem using graphical method and simplex method.
- Understand Integer programming problem.
- Find solutions to linear programming problem by dynamic programming.
- Have the knowledge of Queueing system and classification of Queueing models.
- Solve a variety of deterministic and probabilistic inventory control problems both with and without breaks.
- Understand the concepts of nonlinear programming problems.
- Solve nonlinear programming problems using Wolfs method and Beale's method.
- Derive Wald's fundamental identity and perform sequential analysis.

PROBABILITY AND STATISTICS

Course Code: 21M04DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To study sample moments of distribution functions, concept of statistical test, and methods of finding estimates.
- To gain a working knowledge on analysis of variance and performing sequential analysis.

Unit-I. Probability and random variables: Sample space, probability axioms, finite sample space, Baye's theorem, total probability theorem, independent events,random variables, probability distribution of random variables, discrete and continuous random variables, functions of random variables.

Unit-II. Moment generating functions and multiple random variables: Moments of distribution functions, generating functions, moment inequalities, multiple random variables, independent random variables, functions of several random variables, covariance, correlation, moments, conditional expectations, ordered statistics and their distributions.

Unit-III. Some special distributions and limit theorem: Some discrete distributions, continuous distribution, bivariate and multivariate normal distributions, exponential family of distributions, mode of convergence, weak and strong law of large numbers, limiting moment generating functions, central limit theorem.

Probability measure, random variable, function of random variable, probability mass function, probability density function, cumulative probability distribution function, independent event, expectation, conditional probability, Baye's formula, Baye's theorem, function of several variables, joint and marginal distribution function, moments, moments generating function, characteristic function.

Unit-IV. Sample moments and their distributions: Types of sampling, Sample characteristics and their distributions, Chi square test, T test, F test and their distributions, Large sample theory.

Unit-V. Parameter estimation: Point estimation, unbiased estimation, lower bound and lower bound for variance of estimator, method of moments, maximum likelihood estimators, Baye's and min-max estimation, and principle of equi - variance.

Unit-VI (Advanced topics only for discussion).

Current Contours: Usage of package R

Text book(s):

V.K.Rohatgi and A.K.Md.E. Saleh, An Introduction to Probability and Statistics, Wiley series of probability and statistics, 2nd edn., 2001.

Unit-I: Chapter 1-2
Unit-II: Chapter 3-4
Unit-III: Chapter 5-6
Unit-IV: Chapter 7, 10: Sec.7.1-7.5, Sec. 10.3-10.5
Unit-V: Chapter 8

References.

(1) M. Fisz, Probability Theory and Mathematical Statistics, John Wiley and Sons, New York, 2012
(2) E.J.Dudewicz and S.N.Mishra, Modern Mathematical Statistics, Jobn Wiley and Sons, New York, 1988.
(3) D. C. Montgomery and G. C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons, 6th edn., 2016.
(4) G.G.Roussas, A First Course in Mathematical Statistics, Addison Wesley Publishing Company, 1973.
(5) B.L.Vander Waerden, Mathematical Statistics, G.Allen & Unwin Ltd., London, 1968.

Course Outcomes:

Students will be able to:

- Understand the notion of a sample and a statistic distribution functions of χ^2 distribution, Student t-distribution.
- Calculate sample moments of Fisher's Z-distribution - Snedecor's F-distribution.
- Do the parametric tests for small samples and large samples.
- Can perform tests of Kolmogorov and Smirnov type.
- Use contingency tables to perform independent tests.
- Find asymptotically most efficient estimates and their confidence interval.
- Discuss the analysis of variance on uniformly most powerful test and unbiased test.
- Derive Wald's fundamental identity and perform sequential analysis.

NUMERICAL ANALYSIS

Course Code: 21M05DEC
Prerequisite: 21M03CC

L	T	P	C
4	2	0	5

Objectives.

- To introduce the field of numerical analysis as the design and analysis of techniques to give approximate solutions to difficult problems.
- The indispensable error analysis part has to be emphasized in the course.
- Various numerical methods are used to solve algebraic equations and differential equations.

Unit-I. Transcendental and polynomial equations: Iteration Methods based on Second degree equation - Rate of convergence of iterative methods - Methods for finding complex roots - Polynomial equations - Birge-Vieta method, Bairstow's method.

Unit-II. System of Linear Algebraic equations and Eigen Value Problems: Direct Methods- Gauss Jordan Elimination Method - Triangularization method - Cholesky method - Error Analysis - Iteration Methods - Jacobi iteration method - Gauss - Seidal iteration method - Eigenvalues and Eigen vectors.

Unit-III. Interpolation, Approximation and Differentiation: - Introduction - Hermite Interpolations - Piecewise and Spline Interpolation - Approximation - Least square approximation - Differentiation - Numerical Differentiation - Optimum choice of Step- length - Extrapolation methods

Unit-IV. Differentiation and Integration: - Methods based on interpolation - Methods based on undetermined coefficients - Gauss Legendre integration methods - Lobatto Integration Methods - Radau integration methods.

Unit-V. Ordinary differential equations: Introduction - Numerical Methods- Local truncation error - Euler, Backward Euler, Taylor's Method and second order Runge-Kutta method

Unit-VI (Advanced topics only for discussion).

Current Contours: Methods for partial differential equations

Text book(s):

M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 7th edn., New Age International, 2019.

Unit-I: Chapter 2 - 2.4 to 2.8 of [1].
Unit-II: Chapter 3 - 3.2 to 3.5 of [1].
Unit-III: Chapter 4 - 4.1, 4.5 , 4.6, 4.8,4.9 and 5.2 - 5.4 of [1].
Unit-IV: Chapter 5 - 5.6 - 5.8 of [1].
Unit-V: Chapter 6 - 6.2 and 6.3 of [1].

References.

(1) Kendall E. Atkinson, An Introduction to Numerical Analysis, II Edn., John Wiley & Sons, 1988.

(2) M.K. Jain, Numerical Solution of Differential Equations, 4th edn., New Age International Pvt Ltd., 2018.

(3) Samuel. D. Conte, Carl. De Boor, Elementary Numerical Analysis; An Algorithmic Approach (Updated with MatLab), SIAM, 2018.

(4) George A. Anastassiou, Razvan A. Mezei, Numerical Analysis Using Sage, Springer (UTM), 2016

Course Outcomes:

Students will be able to:

- Solve algebraic and transcendental equations using various iterative methods and study the rate of convergence of those problems.
- Solve System of Linear Algebraic equations using direct methods and indirect methods.
- Solve eigenvalue problems and study the error analysis.
- Solve algebraic equations and differential equations using the techniques of interpolation like Lagrange Interpolation ,Hermite Interpolation etc..
- Perform curve fitting using least square approximation.
- Find the numerical value of the derivative of various functions using Euler method and Runge-Kutta method.
- Calculate the numerical value of a definite integral using methods like quadrature rules in numerical integration.
- Identify the suitable numerical method and perform error analysis.

CLASSICAL DYNAMICS

Course Code: 21M06DEC
Prerequisite: 21M03CC

L	T	P	C
3	2	0	4

Objectives.

- To develop familiarity with the dynamical concepts of Newton, Lagrange and Hamilton.
- To develop skills in formulating and solving physics problems.

Unit-I. Introductory concepts: The mechanical system - Generalised Coordinates - constraints - virtual work - Energy and momentum.

Unit-II. Lagrange's equation: Derivation and examples - Integrals of the Motion.

Unit-III. Hamilton's equations: Hamilton's principle - Hamilton's equations - Other variational principles - phase space.

Unit-IV. Hamilton - Jacobi Theory: Hamilton's Principal Function - The Hamilton - Jacobi equation - Separability.

Unit-V. Canonical Transformations: Differential forms and Generating functions - Special Transformations - Lagrange and Poisson Brackets.

Unit-VI (Advanced topics only for discussion).

Current Contours: Introduction to relativity

Text book(s):

Donald T. Greenwood, Classical Dynamics, Dover, 1997.

Unit-I: Chapter 1: Sections 1.1 to 1.5
Unit-II: Chapter 2: Sections 2.1 to 2.4
Unit-III: Chapter 3: Sections 3.1 - 3.2 and 3.4 (section 3.3 omitted)
Unit-IV: Chapter 4: Sections 4.1 to 4.4
Unit-V: Chapter 5: Sections 5.1 to 5.3

References.

(1) H. Goldstein, Classical Mechanics, (2nd Edition), Narosa Publishing House, New Delhi, 1998.
(2) John L Synge and Byron A Griffith, Principles of Mechanics, 3rd edn., McGraw-Hill, New York, 2017.
(3) Narayan Chandra Rana & Promod Sharad Chandra Joag, Classical Mechanics, Tata McGraw Hill, 1991.

Course Outcomes:

Students will be able to:

- Understand the important definitions and introductory concepts like the ideas of virtual work and d'Alembert's principle.
- Derive Lagrange's equations of motion using d'Alembert's principle.
- Understand the nature of equations of motion for holonomic and nonholonomic systems.
- Understand the idea of impulsive constraints.
- Compare dissipative systems and velocity dependent potentials.

- Understand the Hamiltonian view point of dynamics in canonical equations of motion and phase space.
- Understand the concepts of Hamilton - Jacobi theory.
- Obtain some concrete procedure for solving problems using the theory of canonical transformations.

FLUID DYNAMICS

Course Code: 21M07DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To understand the dynamics of real fluids.
- To acquire the knowledge of solving problems using partial differential equations.

Unit-I. Real Fluids and Ideal Fluids - Velocity of a Fluid at a point - Streamlines and Path lines; Steady and Unsteady Flows - The Velocity potential - The Vorticity vector - Local and Particle Rates of Change - The Equation of continuity - Worked examples - Acceleration of a Fluid - Conditions at a rigid boundary - General analysis of fluid motion - Pressure at a point in a Fluid at Rest - Pressure at a point in Moving Fluid - Conditions at a Boundary of Two Inviscid Immiscible Fluids -Euler's equations of motion - Bernoulli's equation - worked examples.

Unit-II. Discussion of a case of steady motion under conservative body forces - Some potential theorems-Some Flows Involving Axial Symmetry - Some special two- Dimensional Flows - Impulsive Motion. Some three-dimensional Flows: Introduction - Sources, Sinks and Doublets - Images in a Rigid Infinite Plane - Axi-Symmetric Flows; Stokes stream function

Unit-III. Some Two-Dimensional Flows: Meaning of a Two-Dimensional Flow - Use of cylindrical Polar coordinates - The stream function - The Complex Potential for Two- Dimensional, Irrotational, Incompressible Flow - complex velocity potentials for Standard Two-Dimensional Flows - Some worked examples - The Milne-Thomson circle theorem and applications - The Theorem of Blasius.

Unit-IV. The use of conformal Transformation and Hydrodynamical Aspects - Vortex rows. Viscous flow: Stress components in a Real fluid - relations between Cartesian components of stress - Translational Motion of Fluid Element - The Rate of Strain Quadric and Principal Stresses - Some Further properties of the Rate of Strain Quadric - Stress Analysis in Fluid Motion - Relations Between stress and rate of strain - The coefficient of viscosity and Laminar Flow - The Navier - Stokes equations of Motion of a Viscous Fluid.

Unit-V. Some solvable problems in Viscous Flow - Steady Viscous Flow in Tubes of Uniform cross section - Diffusion of Vorticity - Energy Dissipation due to Viscosity - Steady Flow past a Fixed Sphere - Dimensional Analysis; Reynolds Number - Prandtl's Boundary Layer.

Unit-VI (Advanced topics only for discussion).

Current Contours: Gas Dynamics and Magnetohydrodynamics.

Text book(s):

F. Chorlton, Text Book of Fluid Dynamics, CBS Publishers & Distributors, New Delhi, 1985.

Unit-I:	Chapter 2 and Chapter 3: Sections 3.1 to 3.6
Unit-II:	Chapter 3: Sections 3.7 to 3.11 and Chapter 4: Sections 4.1, 4.2, 4.3, 4.5
Unit-III:	Chapter5 : Sections: 5.1 to 5.9 except 5.7
Unit-IV:	Chapter 5: Section 5.10 , 5.12 and Chapter 8: Sections 8.1 to 8.9
Unit-V:	Chapter 8: Sections 8.10 to 8.16

References.

(1) J.F. Wendt, J.D. Anderson, G.Degrez and E. Dick, Computational Fluid Dynamics : An Introduction, Springer-Verlag, 1996.

(2) J.D. Anderson, Computational Fluid Dynamics, The Basics with Applications, McGraw Hill, 2017.

(3) G.K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, New Delhi, 2005.

(4) A.J. Chorin and A. Marsden, A Mathematical Introduction to Fluid Dynamics, Springer-Verlag, New York, 1993.

(5) S.W. Yuan, Foundations of Fluid Mechanics, Prentice Hall of India Pvt Limited, New Delhi, 1976.

(6) R.K. Rathy, An Introduction to Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi, 1976.

Course Outcomes:

Students will be able to:

- Understand the basic ideas of fluid velocity, streamlines and rotational and irrotational flows
- Understand the meanings of fundamental terms like pressure and body force.
- Develop special mathematical methods involving images and complex variables for incompressible fluids.
- Derive images in three dimension.
- Solve problems using Milne-Thomson circle theorem.
- Understand Navier's stokes of motion
- Unify many developed principles.
- Solve problems related with cosmic electrodynamics and nuclear engineering.

OPERATOR THEORY

Course Code: 21M08DEC
Prerequisite: 21M12CC

L	T	P	C
3	2	0	4

Objectives.

- The idea behind the second course on functional analysis is to emphasize very basic results which are left out in the first course and are important for analysts who apply these tools.
- To study compact operators, spectral theory of Banach space operators and Hilbert space operators, Banach algebras and Gelfand Naimark theorem.

Unit-I. Review of Five Pillars of Functional Analysis - Compact operators

Unit-II. Dual Spaces - Adjoint Operators - Hilbert Space Adjoint

Unit-III. Banach Algebras - Spectrum of an Element in a Banach Algebra - Spectrum of Some Standard Operators

Unit-IV. Finite dimensional Spectral theorem - Spectral theorem for Hermitian Operators - Corollaries of the Spectral theorem -Spectral Measures

Unit-V. Generating topologies - Weak and Weak* topologies - Banach Alaoglu Theorem
Unit-VI (Advanced topics only for discussion).
Current Contours: Locally Convex Topological Vector spaces
Text book(s): S.Kumaresan and D.Sukumar, Functional Analysis A first course, Narosa Publishing House, 2020.

Unit-I:	Chapter 2, Chapter 3: Skip Subsections 2.1.1, 2.5.1, 2.6.1.3-2.6.1.5
Unit-II:	Chapter 4
Unit-III:	Chapter 5
Unit-IV:	Chapter 6
Unit-V:	Chapter 7
Unit-VI:	Chapter 8

References.

(1) B. Bollobas, Linear Analysis an introductory course, 2nd edn, Cambridge Mathematical Texts, Cambridge University Press, 1999.
(2) B.V. Limaye, Functional Analysis, Revised 3rd edn, New Age International, 2014.
(3) C. Goffman and G. Pedrick, A First Course in Functional Analysis, AMS, Chelesea, 2017
(4) B. Rynne and M.A. Youngson, Linear Functional Analyis, Springer UMS, 2008
(5) E. Kreyszig, Introductory Functional Analysis with applications, John Wiley, 2007.
(6) S. Kesavan, Functional Analysis, Hindustan book agency, 2014.
(7) G.F.Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2017.
(8) M.Thamban Nair, Functional Analysis: A first course, Prentice Hall of India, 2002.
(9) K. Yosida, Functional Analysis, Springer-Verlag, 1995.

Course Outcomes:

Students will be able to:

- Revise the important four pillars of functional analysis namely Hahn- Banach theorem, Open mapping theorem, Closed graph theorem, Uniform boundedness principles.
- Find dual spaces and their representations and tabulate them.
- Gain mastery in compact operators and spectral results on these operators.
- Get a working knowledge on algebra of bounded linear operators on Normed linear spaces.
- Compute eigen spectrum, approximate eigen spectrum and spectrum of various operators and study their interconnections.
- Study in detail the spectral properties of Hilbert space operators.
- Understand spectral theory of compact self adjoint operators.
- Learn weak topologies on a normed linear space and understand the importance of Banach Alaoglu Theorem.

INTEGRAL TRANSFORMS

Course Code: 21M09DEC
Prerequisite: 21M03CC

L	T	P	C
3	2	0	4

Objectives.

- The central theme of the course is to get an intensive training in the techniques of integral transforms and to apply them in practical problems eminating from various fields.
- The Laplace transforms and the Fourier transforms are dealt both with rigour and with lot examples and applications.

Unit-I. Laplace transforms - Important properties - Simple Applications- Asymptotic Properties - Watson's Lemma.

Unit-II. Inversion Integral- The Riemann - Lebesgue Lemma - Dirichlet Integrals - the Inversion - Watson's Lemma for loop integrals- Heaviside series expansion.

Unit-III. Application to ordinary differential equations - Elementary examples - Higher order equations - Partial differential equations - Heat diffusion integral equations.

Unit-IV. Fourier transforms - Exponential- Sine and Cosine transforms- Important properties - Spectral analysis.

Unit-V. Partial differential equations - Potential problems-Water waves - Basic equations - Waves generated by a Surface displacement.

Unit-VI (Advanced topics only for discussion).

Current Contours: Functional and complex analytic ideas developed.

Text book(s):

B. Davies, Integral Transforms and Their Applications,Springer, Texts in Applied Mathematics, 41 Third Edition,2009.

Unit-I:
Unit-II:
Unit-III:
Unit-IV:
Unit-V:

References.

(1) Ian N. Snedden, The Use of Integral Transforms, McGraw Hill, 1972.
(2) Lokenath Debnath and D. Bhatta, Integral Transforms and Their Applications, 2nd edn., CRC, 2006.

Course Outcomes:

Students will be able to:

- Understand Laplace transforms and get expertise in simple applications.
- Watson's lemma will be understood in depth.
- To get inverse Laplace transforms for a wide range functions.
- Understand the Heavyside series expansion.
- Apply the theory to ODE and PDE.
- Discuss in detail the application to Heat and diffusion equations.
- Appreciate the theory of Fourier transform and its mathematical depth.
- Will be able to solve problems formulated in mathematical modelling of Water waves.

STOCHASTIC PROCESSES

Course Code: 21M10DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To motivate stochastic processes and in particular Markov chains are the ones which are widely used as mathematical models of systems and phenomena that appear to vary in a random manner.
- To study Markov chainsRiemann-Stieltjes integrals - Po, Markov processes with discrete and continuous state space, renewal processes in continuous time and Morkovian queuing models.

Unit-I. Stochastic Processes: Some notions - Specification of Stochastic processes Stationary processes - Markov Chains - Definitions and examples - Higher Transition probabilities - Generalization of Independent Bernoulli trails - Sequence of chain - Dependent trails.

Unit-II. Markov chains: Classification of states and chains - determination of Higher transition probabilities - stability of a Markov system - Reducible chains - Markov chains with continuous state space.

Unit-III. Markov processes with Discrete state space : Poisson processes and their extensions - Poisson process and related distribution - Generalization of Poisson process- Birth and Death process - Markov processes with discrete state space (continuous time Markov Chains).

Unit-IV. Renewal processes and theory : Renewal process - Renewal processes in continuous time - Renewal equation - stopping time - Wald's equation - Renewal theorems.

Unit-V. Stochastic processes in Queuing - Queuing system - General concepts - the queuing model $M/M/1$ - Steady state behaviour - transient behaviour of $M/M/1$ Model - Non-Markovian models - the model $GI/M/1$.

Unit-VI (Advanced topics only for discussion).

Current Contours: Branching Processes

Text book(s):

J. Medhi, Stochastic Processes, 5th edn., New Age International, 2020.

Unit-I:	Ch. II : Sec 2.1 to 2.3, Ch III : Sec 3.1 to 3.3
Unit-II:	Ch III - Sec 3.4 to 3.6, 3.8, 3.9 and 3.11
Unit-III:	Ch IV : Sec 4.1 to 4.5
Unit-IV:	Ch VI : Sec 6.1 to 6.5
Unit-V:	Ch X : Sec 10.1 to 10.3, 10.7 and 10.8 (omit sec 10.2.3 & 10.2.3.1)

References.

(1) Samuel Karlin, Howard M. Taylor, A first course in stochastic processes, 2nd edition, Academic Press, 1975.
(2) Narayan Bhat , Elements of Applied Stochastic Processes, 2nd edn, John Wiley, 1984.
(3) S.K. Srinivasan and K.Mehata, Stochastic Processes, Tata McGraw Hill, 1976.

(4) N.U. Prabhu, Stochastic Processes: Basic Theory and its Applications, World Scientific Publishers, 2007.

Course Outcomes:

Students will be able to:

- Give specification of stochastic process and give examples for steady process.
- Understand Markov chains and explain the generalization of Independent Bernoulli trails.
- Classify states and chains and discuss stability of a Markov system.
- Have working knowledge on Markov chains with continuous state space.
- Identify and work on Markov process with discrete and continuous state space.
- Describe renewal processes in continuous time using Wald's equation.
- Demonstrate and apply renewal theorems.
- Analyze transient behaviour of Queuing models.

CODING THEORY

Course Code: 21M11DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To learn how codes in mathematics are used for error correction and data transmission.
- To comprehend the algebraic structure of linear codes viewed as a vector space over a finite field

Unit-I. Linear Code: Introduction - Linear codes, Encoding, Decoding - Check Matrices and Dual Code.

Unit-II. Linear Code continued: Classification by Isometry - Semilinear Isometry Classes of Linear codes - The Weight Enumerator.

Unit-III. Bounds and Modifications: Combinatorial Bounds for the Parameters - New Codes from Old and Minimum distance - Further Modifications and Constructions.

Unit-IV. Reed Muller Codes - MDS Codes.

Unit-V. Cyclic Codes: Cyclic Codes as Group Algebra Codes - Polynomila Representaion of Cyclic Codes - BCH Codes and Reed-Solomon Codes.

Unit-VI (Advanced topics only for discussion).
Current Contours: Graph Codes - Identifying codes.

Text book(s):

(1) Anton Betten, Michael Braun, Harald Fripertinger, Adalbert Kerber, Axel Kohnert and Alfred Wassermann, Error-Correcting Linear Codes, Classification by Isometry and Applications, Springer-Verlag, 2006.

Unit-I: Chapter 1 (Section 1.1 - 1.3)
Unit-II: Chapter 1 (Section 1.4 - 1.6)
Unit-III: Chapter 2 (Section 2.1 - 2.3)
Unit-IV: Chapter 2 (Section 2.4 & 2.5)
Unit-V: Chapter 4 (Section 4.1 - 4.3)

References.

(1) F. J Mac Williams and N. J. A. Sloane, The Theory of Error-Correcting Codes, North Holland Publishing Company 1977.
(2) D.G. Hoffman et al, Coding Theory: The Essentials, CRC, 2000.
(3) S. Ling and C. Xing, Coding Theory : A first course, Cambridge University press, 2004.

Course Outcomes:

After completing this course, the student will be able to:

- Coding theory demonstrates how mathematics is used in real life applications.
- Students get thorough idea about channel, noise, encoding, decoding etc and also error detection and error correction which are involved in a data communication.
- One can have a clear cut idea about parameters of codes and the aims of constructing codes with minimum length and maximum number of codewords and maximum distance.

- To learn how finite fields, vector space, number theory and probability theory are applied in Coding Theory.
- To acquire the knowledge of efficient decoding schemes of various linear codes.
- To understand various bounds involved in coding theory and how it is used for proving non-existence of codes under certain situation.
- To practice how to construct new codes from the existing codes and learn more about the parameters of the newly obtained codes.
- To get expertise in some important codes like Hamming code, Golay code and Reed-Muller code and thier applications to information theory.

FIXED POINT THEORY

Course Code: 21M12DEC
Prerequisite: 21M02CC

L	T	P	C
3	2	0	4

Objectives.

- To understand the concept of fixed point theorem for various spaces.
- To learn the concept of uniformly convex banach spaces and Tarsiki's fixed point theorem.

Unit-I. Banach's contraction principle - Further extensions- Caristi - Ekeland principle - Equivalance of Caristi- principles.

Unit-II. Tarsiki's Fixed point theorem - Hyperconvex spaces - Properties - fixed point theorems - intersection of hyper convex spaces - Isbell's convex hull.

Unit-III. Uniformly convex Banach spaces - Fixed point theorem of Browder, Gohde and Kirk. Reflexive Banach spaces - Normal structure- Fixed point theorems.

Unit-IV. Generalized Banach Fixed-point theorem- Upper and lower semi continuity of multivalued maps - Generalized Schauder Fixed point theorem - Variational Inequalities and the Browder Fixed-Point theorem - Extremal Principle - Applications to Game Theory - Michael's selection theorem

Unit-V. Fixed point theorem for continuous functions- Brouwer's theorem -Schauder's theorem - applications - Hairy ball theorem - pancake problems- Kyfan's best approximation theorem.

Unit-VI (Advanced topics only for discussion).

Current Contours: Generalizations of Brouwer's fixed point theorem. Best proximity pairs.

Text book(s):

(1) E. Zeidler, Nonlinear Functional Analysis and its applications, Vol. I Springer - Verlag New york (1986).
(2) M. A. Khamsi & W. A. Kirk, An introduction of Metric spaces and Fixed point theory, John Wiley & sons (2001).

Unit-I: Chapter 3 (3.1 - 3.4) from [2]
Unit-II: Chapter 4 from [2]
Unit-III: Chapter 10 (10.1 -10.3) from[1] and chapter 5 (5.1 -5.4) from [2]
Unit-IV: Chapter 9 from [1]
Unit-V: Chapter 2 from [1]

References.

(1) D.R. Smart, Fixed point theory, Cambridge University Press, (1974).
(2) V.I. Istratescu, Fixed point theory, D. Reidel Publsihing Company, Boston (1979).

Course Outcomes:

Students will be able to:

- Appreciate how the study of fixed point theory helps to solve problems which are theoretical as well as practical.
- Realize contraction, contractive maps have elegant results on the existence and uniqueness of fixed points.
- Study the theory of non-expansive fixed point theorems and understand the geometry of the spaces involved.
- Understand the depth of mathematical concepts required to give the proof Brouwer's fixed point theorem due to Milnor.
- Appreciate the generalizations of Brouwer's fixed point theorem, viz., Schauder and the use of it in analysis and differential equations.
- Comprehend the fixed point theory on multivalued maps and see the interconnection with single valued cases.
- Thoroughly understand the idea behind Michael's selection theorem.
- Understand Kyfan's best approximation theorem and its consequences.

DISCRETE DYNAMICAL SYSTEM

Course Code: 21M13DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To Understand and appreciate the topological dynamics and Chaotic systems.
- To gain mastery in Symbolic dynamics.

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.

Unit-VI (Advanced topics only for discussion).

Current Contours: Give glimpse on the topics such as Cellular Autamata: Transitivity: Linear Chaos: Continuous Dynamical systems.

Text book(s):

(1) Richard A. Holmgren, A First Course in Discrete Dynamical Systems, 2nd edn, Springer Verlag, 2000.

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.

References.

(1) Robert L.Devaney, A First Course in Chaotic Dynamical Systems, 2nd edn, CRC Press, 2020.

Course Outcomes:

Students will be able to:

- Appreciate the basics of topological dynamics with the help of illustrous examples.
- Understand that not only period three maps or chaotic, there are lot more. Using Sarkoviskii's theorem.
- Discuss on the concept of attracting and repelling periodic points.
- Understand the theory of bifurication and understand and apply them.
- Will be will versed in Symbolic dynamics.
- Get an expertise in topological conjugacy.
- Will thoroughly understand Newton's method in the perview of DDS.
- Appreciate complex dynamics. Self similarity and Mendolbortt sets will be there favourite topics to discuss.

ALGEBRAIC TOPOLOGY

Course Code: 21M14DEC
Prerequisite: 21M08CC

L	T	P	C
3	2	0	4

Objectives.

- To introduce algebraic invariant, homology groups for simplicial complexes.
- To demonstrates the power of topological methods in dealing with problems involving shape and position of continuous mappings.

Unit-I. Revision of Basic topological concepts: Revision on point set topology: Closed - Compact - Connected sets -Quotient topology.

Unit-II. Fundamental Group: Homotopy - Fundamental group.

Unit-III. Covering spaces: Covering map - Covering homotopy theorem - Regular covering spaces.

Unit-IV. Simplicial complexes: Geometry of Simplicial complexes - Barycentric subdivisions.

Unit-V. Simplicial complexes: Simplicial approximation theory - Fundamental group of a Simplicial complex.

Unit-VI (Advanced topics only for discussion).

Current Contours: Homology theory

Text book(s): I.M. Singer and J.A. Thorpe, Lecture Notes on Elementary Topology and Geometry, Springer, 2012.

Unit-I: Chapter 1 and 2
Unit-II: Chapter 3 (Section: 3.1 to 3.2)
Unit-III: Chapter 3 (Section: 3.3)
Unit-IV: Chapter 4 (Section: 4.1 to 4.2)
Unit-V: Chapter 4 (Section: 4.3 to 4.4).

References.

(1) W. Rudin, Real and Complex Analysis, 3rd edition, McGraw Hill International, 2017.
(2) James R. Munkres, Topology (2nd Edition), Pearson Education India, 2015.

Course Outcomes:

Students will be able to:

- Review the basic topological concepts connecting geometry.
- Understand quotient topology and how the identification works.
- Discuss on the concept of homotopy and homotopy equivalence of topological spaces.
- Compute the fundamental groups of standard topological spaces.
- Learn thoroughly covering homotopy theorem.
- Use simplicial approximations to find the fundamental group of simplicial complexes.
- Appreciate and deduce the important Brouwer's fixed point theorem.

DISCRETE MATHEMATICS

Course Code: 21M15DEC
Prerequisite: Nil

L	T	P	C
3	2	0	4

Objectives.

- To train the students to get expertise in the mathematical concepts involved in the field Discrete Mathematics which has applications in diverse areas including Computer science and Electrical Engineering.
- To learn the basic concepts in combinatorics and the idea of tackling problems using generating functions and recurrence relation.
- Also, in this course, the rudiments of Graph theory viz., Paths and connectedness of Graphs, Matching, Planarity, Vertex colourings, Edge colourings, are introduced.

Unit-I. Combinatorics; Sequences: Stirling Numbers: A Preview - Ordinary Generating Functions - Synthesizing Generating Functions.

Unit-II. Solving Recurrences: Types of Recurrences - Finding Generating Functions - Partial Fractions - Characterstic Roots - Simultaneous Recursions.

Unit-III. Graph Theory ; Basic results: Basic Concepts - Subgraphs - Degrees of Vertices - Paths and Connectedness
Connectivity : Vetex Cuts and Edges Cuts - Connectivity and Edge connectivity - Blocks - Cyclical Edge Connectivity of a graph - Menger's Theorem.

Unit-IV. Independent Sets and Matchings: Vertex Independent Sets and Vertex Coverings - Edge - Independent Sets - Matchings and Factors - Matchings in Bipartite Graphs.

Unit-V. Planarity: Planar and Nonplanar Graphs - Euler Formula and its Consequences - K5 and K(3,3) are Nonplanar Graphs - Dual of a Plane Graph - The Four-Color theorem and the Heawood Five-Color Theorem - Kuratowski's Theorem - Hamiltonian Plane Graphs - Tait Coloring.

Unit-VI (Advanced topics only for discussion).
Current Contours: Perron -Frobenius theorem and Google's Page rank.

Text book(s):

(1) Jonathan L. Gross, Combinatorial Methods with Computer Applications, Chapman & Hall /CRC, New York, 2008.
(2) R, Balakrishnan and K.Ranganathan, A Textbook of Graph Theory, Second Edition, Springer, New York, 2012.

Unit-I:	Chapter 1 (Section 1.6 - 1.8) of [1]
Unit-II:	Chapter 2 (Section 2.1 - 2.5) of [1]
Unit-III:	Chapter 1 and Chapter 3 of [2]
Unit-IV:	Chapter 5 (Sections 5.1 -5.5) and Chapter 7 (Section 7.1 - 7.3) of [2]
Unit-V:	Chapter 8 of [2]

References.

(1) C.L. Liu, Elements of Discrete Mathematics, 4th edn, McGraw-Hill, 2017.

(2) P. Tremblay and R. Manohar, Discrete Mathematical Structures with Applications to Computer Science, McGraw-Hill, 2017

(3) Bondy J.A. and U.S.R. Murty, Graph Theory with Applications. North Holland, New York ,1976.

Course Outcomes:

After completing this course, the student will be able to:

- Review and explain the techniques required in addressing problems on permutations and combinations. For illustration, finding how the distribution of distinct objects into non distinct cells are made helps the students to gain the impetus of the subject.
- Explain how the technique of generating functions and recurrence functions are used to solve the problems in combinatorics.
- Detail about simultaneous recurrences and use it to solve more problems.
- Understand and work on the elementary concepts of graphs namely, subgraph, cut vertex, blocks.
- Discuss matching problems and its applications elsewhere.
- Workout in detail the connectivity of a given graph with help of Menger's theorem.
- Comprehend and work on the concepts of planarity and discuss the dual of a plane graph.
- Elucidate on the famous Four-Color theorem and discuss Tait Coloring.

PROBABILITY THEORY

Course Code: 21M16DEC
Prerequisite: 21M11CC

L	T	P	C
4	2	0	5

Objectives.

- To provide mathematical foundation for statistics
- To study the discrete and continuous random variables, statistical parameters on probability distributions and central limit theorems.

Unit-I. Random Events and Random Variables - Random events - Probability axioms Combinatorial formulae - conditional probability - Bayes Theorem - Independent events Random Variables - Distribution Function - Joint Distribution - Marginal Distribution - Conditional Distribution - Independent random variables - Functions of random variables.

Unit-II. Parameters of the Distribution - Expectation- Moments - The Chebyshev Inequality - Absolute moments - Order parameters - Moments of random vectors - Regression of the first and second types.

Unit-III. Characteristic functions - Properties of characteristic functions - Characteristic functions and moments - semi-invariants - characteristic function of the sum of the independent random variables - Determination of distribution function by the Characteristic function - Characteristic function of multidimensional random vectors - Probability generating functions.

Unit-IV. Some Probability distributions - One point , two point , Binomial - Polya - Hypergeometric - Poisson (discrete) distributions - Uniform - normal gamma - Beta - Cauchy and Laplace (continuous) distributions.

Unit-V. Limit Theorems - Stochastic convergence - Bernaulli law of large numbers Convergence of sequence of distribution functions - Levy-Cramer Theorems - de Moivre- Laplace Theorem - Poisson, Chebyshev, Khintchine Weak law of large numbers - Lindberg Theorem - Lapunov Theroem - Borel-Cantelli Lemma - Kolmogorov Inequality and Kolmogorov Strong Law of large numbers.

Unit-VI (Advanced topics only for discussion).

Current Contours: Measure theoretic introduction to probability theory.

Text book(s):

M. Fisz, Probability Theory and Mathematical Statistics, John Wiley and Sons, New York, 2012.

Unit-I:	Chapter 1: Sections 1.1 to 1.7, Chapter 2 : Sections 2.1 to 2.9.
Unit-II:	Chapter 3 : Sections 3.1 to 3.8.
Unit-III:	Chapter 4 : Sections 4.1 to 4.7.
Unit-IV:	Chapter 5 : Section 5.1 to 5.10 (Omit Section 5.11).
Unit-V:	Chapter 6 : Sections 6.1 to 6.4, 6.6 to 6.9 , 6.11 and 6.12. (Omit Sections 6.5, 6.10,6.13 to 6.15).

References.

(1) W. Feller, An Introduction to Probability Theory and its Applications, Vol 1, 3rd edn, Wiley, 2008

(2) R.B. Ash, Real Analysis and Probability, Academic Press, New York, 1972

(3) K.L.Chung, A course in Probability, Academic Press, New York, 1974.

(4) K.R. Parthasarathy, Introduction to Probability and measure, Texts and Readings in Mathematics 22, Hindustan Book Agency, 2002.

(5) R. Durrett, Probability : Theory and Examples, 5th edn., Cambridge University Press, 2019.

(6) V.K.Rohatgi An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi, 1988(3rd Print).

(7) P. Billingsley, Probability and Measure, 4th edn., John Wiley, 2012.

(8) B.R.Bhat , Modern Probability Theory (4th Revised Edition), New Age International (P)Ltd, New Delhi, 2019.

(9) J.P. Romano and A.F. Siegel, Counter Examples in Probability and Statistics, Wadsworth and Brooks / Cole Advanced Books and Software, California, 1968.

Course Outcomes:

Students will be able to:

- Understand Probability axioms and find conditional probabilities for lot of cases.
- Use Baye's theorem to calculate probabilities for various examples
- Distinguish and work on joint, marginal and conditional distribution.
- Compute expectations and moments on a number of distributions.
- Identify the regression of first and second type and analyse them.
- Determine the distribution function using characteristic function.
- Gain mastery in the important probability distributions, viz., Binomial, Poisson and Normal.
- Derive the central limit theorems and Bernaulli law of large numbers
- Study Borel-Cantelli Lemma, Kolmogorov Inequality and Kolmogorov Strong Law of large numbers.

MATHEMATICAL STATISTICS

Course Code: 21M17DEC
Prerequisite: 21M07CC

L	T	P	C
3	2	0	4

Objectives.

- To study sample moments of distribution functions, concept of statistical test, and methods of finding estimates.
- To gain a working knowledge on analysis of variance and performing sequential analysis.

Unit-I. SAMPLE MOMENTS AND THEIR FUNCTIONS: Notion of a sample and a statistic - Distribution functions of χ^2, s^2 and $(\chi 2, s^2) - \chi^2$ distribution - Student t-distribution - Fisher's Z-distribution - Snedecor's F-distribution - Distribution of sample mean from non-normal populations.

Unit-II. SIGNIFICANCE TEST: Concept of a statistical test - Parametric tests for small samples and large samples - c2 test Kolmogorov Theorem 10.11.1 - Smirnov Theorem 10.11.2 - Tests of Kolmogorov and Smirnov type - The Wald-Wolfovitz and Wilcoxon-Mann-Whitney tests - Independence Tests by contingency tables.

Unit-III. ESTIMATION: Preliminary notion - Consistency estimation - Unbiased estimates - Sufficiency - Efficiency - Asymptotically most efficient estimates - methods of finding estimates - confidence Interval.

Unit-IV. ANALYSIS OF VARIANCE: One way classification and two-way classification. Hypotheses Testing Poser functions - OC function- Most Powerful test - Uniformly most powerful test - unbiased test.

Unit-V. SEQUENTIAL ANALYSIS: SPRT - Auxiliary Theorem - Wald's fundamental identity - OC function and SPRT - E(n) and Determination of A and B - Testing a hypothesis, concerning p on 0-1 distribution and m in Normal distribution.

Unit-VI (Advanced topics only for discussion).

Current Contours: Usage of package R

Text book(s):

M. Fisz, Probability Theory and Mathematical Statistics, John Wiley and Sons, New York, 2012.

Unit-I:	Chapter 9 : Sections 9.1 to 9.8
Unit-II:	Chapter 10 : Sections 10.11, Chapters 11,12 Sections : 12.1 to 12.7.
Unit-III:	Chapter 13 : Sections 13.1 to 13.8 (Omit Section 13.9)
Unit-IV:	Chapter 15 : Sections 15.1 and 15.2 (Omit Section 15.3)
	Chapter 16 : Sections 16.1 to 16.5 (Omit Section 16.6 and 16.7)
Unit-V:	Chapter 17 : Sections 17.1 to 17.9 (Omit Section 17.10)

References.

(1) E.J.Dudewicz and S.N.Mishra, Modern Mathematical Statistics, John Wiley and Sons, New York, 1988.

(2) V.K.Rohatgi An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi, 1988(3rd Print).

(3) G.G.Roussas, A First Course in Mathematical Statistics, Addison Wesley Publishing Company, 1973.

(4) B.L.Vander Waerden, Mathematical Statistics, G.Allen & Unwin Ltd., London, 1968.

Course Outcomes:

Students will be able to:

- Understand the notion of a sample and a statistic distribution functions of χ^2 distribution, Student t-distribution.
- Calculate sample moments of Fisher's Z-distribution - Snedecor's F-distribution.
- Do the parametric tests for small samples and large samples.
- Can perform tests of Kolmogorov and Smirnov type.
- Use contingency tables to perform independent tests.
- Find asymptotically most efficient estimates and their confidence interval.
- Discuss the analysis of variance on uniformly most powerful test and unbiased test.
- Derive Wald's fundamental identity and perform sequential analysis.

NON-MAJOR ELECTIVE COURSES

OBJECT ORIENTED PROGRAMMING using C++

Course Code: 21M01UEC
Prerequisite: +2 level Mathematics

L	T	P	C
2	0	1	2

Objectives.

- To introduce programming style that is associated with the concept of class, objects and other concepts revolving around these two, like inheritance and polymorphism.
- To realize object-oriented programming is a vast improvement over procedural programs.

Unit-I. Programming Paradigms - Introduction to OOP - Advantages of OOP-Characteristics of OO languages - Overview of C++ - C++ programming basics - Functions: Simple Functions - Call by value - Call by reference - Returning values of different type - Function overloading - inline functions - Default arguments - Recursive functions.

Unit-II. Class - Objects - Constructors - Destructors - Objects as function arguments - Returning objects from functions - Structures and Classes - Static data - Static function - Array of objects.

Unit-III. Access specifiers - Friend function - Friend class - Operator overloading - Type casting - Pointers - Template.

Unit-IV. Inheritance - Derived class constructors - Class hierarchies - Types of inheritance - Virtual base class - Function overriding - Virtual functions - Pure virtual functions - Abstract class.

Unit-V. Files and Streams: I/O manipulators - Streams - Error handling during file operations String I/O - Character I/O - Object I/O - I/O with multiple objects - File pointers - Disk I/O with member functions.

Unit-VI (Advanced topics only for discussion). Current Contours: Object oriented software development

Text book(s):

Robert Lafore, Object-Oriented Programming in Microsoft C++, Galgotia Publications, New Delhi, 2000.

Unit-I: Chapters 1, 2 and 3
Unit-II: Chapters 4 and 5
Unit-III: Chapters 6 and 7
Unit-IV: Chapters 9 and 10
Unit-V: Chapters 11 and 12

References.

(1) E.Balagurusamy, Object-Oriented Programming with C++, Second Edition, 2002.
(2) Bjarne Stroustrup, The C++ Programming Language, Addison-Wesley, New York,1999.
(3) StephenPrata,"C++ Primer Plus", 6th Edition ,Addison-Wesley Professional, 2011.

Course Outcomes:

Students will be able to

- Understand that object oriented programs are organized around objects, which contain both data and functions that act on that data and aclass is a template for a number of objects.
- Study how Inheritance allows a class to be derived from an existing class without modifying it
- Learn programming basics, viz., simple functions, call by value and reference, returning values of different type, function overloading, and recursive functions.
- Appreciate with examples structures and classes, static data, static function and array of objects.
- Explain the concepts of operator overloading, type casting pointers and work on templates.
- Identify class hierarchies and types of inheritance.
- Master the concept in files and streams and error handling during file operations
- Have a working knowledge of Disk I/O operations with member functions.

RESOURCE MANAGEMENT TECHNIQUES

Course Code: 21M02UEC
Prerequisite: Nil

L	T	P	C
2	0	1	1

Objectives.

- To introduce operations research and study the techniques which offers enormous practical.
- To have a basic working knowledge on Linear programming, Transportation problems, game theory and network scheduling.

Unit-I. Linear programming problem - Mathematical formulation - Graphical solution and extension - Simplex method.

Unit-II. Duality in Linear programming.

Unit-III. Transportation problem - Assignment problem.

Unit-IV. Game Theory.

Unit-V. Network Scheduling by PERT/CPM.

Unit-VI (Advanced topics only for discussion). Current Contours: Network flows
Text book(s): Kanti Swarup, P. K. Gupta, Man Mohan, Operations Research, Sultan Chand and Sons, 2010.

Unit-I: Chapters 2, 3 and 4
Unit-II: Chapter 5
Unit-III: Chapters 10 and 11
Unit-IV: Chapters 17
Unit-V: Chapters 25

References.

(1) Bazaara, Jarvis and Sherali, Linear Programming and Network Flows, 2th ed., John Wiley.
(2) Hamdy Taha, Operations Research, Pearson Education.

Course Outcomes:

Students will be able to

- Do mathematical formulation of a real life problem into a linear programming problem.
- Solve linear programming problem using graphical method and understand basic feasible solution and optimal solution geometrically.
- Understand simplex method and revised simplex method and apply the algorithms to solve a plenty of problems.
- Understand duality in linear programming problem and solve them.
- Find solutions to transportation problems by various techniques.
- Gain the knowledge of modeling of assignment problem and techniques to solve them.
- Comprehend two person zero sum game in game theory and solve a plenty of them.
- Solve networking problems using PERT/ CPM methods.

MATHEMATICAL MODELLING

Course Code: 21M03UEC
Prerequisite: Nil

L	T	P	C
2	1	0	2

Objectives.

- To introduce the concepts of mathematical modelling .
- To give a wide range view of applications of mathematics in science and technology.

Unit-I. Mathematical Modelling through Ordinary Differential Equations of First order : Linear Growth and Decay Models - Non-Linear Growth and Decay Models - Compartment Models - Dynamics problems - Geometrical problems.

Unit-II. Mathematical Modelling through Systems of Ordinary Differential Equations of First Order : Population Dynamics - Epidemics - Compartment Models - Economics - Medicine, Arms Race, Battles and International Trade - Dynamics.

Unit-III. Mathematical Modelling through Ordinary Differential Equations of Second Order: Planetary Motions - Circular Motion and Motion of Satellites - Mathematical Modelling through Linear Differential Equations of Second Order - Miscellaneous Mathematical Models.

Unit-IV. Mathematical Modelling through Difference Equations : Simple Models - Basic Theory of Linear Difference Equations with Constant Coefficients - Economics and Finance - Population Dynamics and Genetics - Probability Theory.

Unit-V. Mathematical Modelling through Graphs : Solutions which can be Modelled through Graphs - Mathematical Modelling in Terms of Directed Graphs, Signed Graphs, Weighted Digraphs and Unoriented Graphs.

Unit-VI (Advanced topics only for discussion). Mathematical Modelling through mathematical programming, maximum principle and maximum entropy principle.

Text book(s): J.N. Kapur, Mathematical Modelling, Wiley Eastern Limited, New Delhi, 1988.

References.

(1) J. N. Kapur, Mathematical Models in Biology and Medicine, Affiliated East - West Press Pvt Limited, New Delhi, 1981.

Course Outcomes:

Students will be able to

- Understand the concept of a mathematical model and explain the series of steps involved in mathematical modelling .
- Classify different classes of mathematical models.
- Discuss features of a good model and the benefits of using a mathematical model.
- Identify some simple real-life problems that can be solved using mathematical models.
- Convert the physical problems as differential equations through mathematical modelling.

- Use the ideas of directed graphs, weighted digraphs and unoriented graphs for modelling real life problems.
- Model the problems in economics and finance, population dynamics and genetics.
- Solve problems in engineering, physical, biological, social and behavioral sciences.

STATISTICS

Course Code: 21M04UEC
Prerequisite: Nil

L	T	P	C
2	1	0	2

Objectives.

- To introduce the concepts involved in basic statistics and learn them with plenty of demonstrating examples
- To emphasize the correct statistical tools required to analyze and understand the results based on them.

Unit-I. Collection, classification and tabulation of data, graphical and diagrammatic representation - Bar diagrams, Pie diagram, Histogram, Frequency polygon, frequency curve and Ogives.

Unit-II. Measures of central tendency - Mean, Median and Mode in series of individual A short introduction on the use of statistical package RobseUnderstand the concept of a mathematical model and explain the series of steps involved in mathematical modelling .

Unit-III. Measures of dispersion - Range, Quartile deviation, Mean deviation about an average, Standard deviation and co-efficient of variation for individual, discrete and continuous type data.

Unit-IV. Correlation - Different types of correlation - Positive, Negative, Simple, Partial Multiple, Linear and non-Linear correlation. Methods of correlation - Karlpearson's Spearman's correlations and Concurrent deviation .

Unit-V. Regression types and method of analysis, Regression line, Regression equations, Deviation taken from arithmetic mean of X and Y, Deviation taken from assumed mean, Partial and multiple regression coefficients - Applications

Unit-VI (Advanced topics only for discussion). Current Contours: A short introduction on the use of statistical package R
Text book(s): S.C.Gupta, V.K.Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi, 1994.

References.

(1) Freund J.E.(2001); Mathematical Statistics, Prentice Hall of India.
(2) Goon, A.M., Gupta M.K., Dos Gupta, B, (1991), Fundamentals of Statistics, Vol.I, World Press, Calcutta.

Course Outcomes:

Students will be able to

- Collect, classify and tabulate a given data and study graphical and diagrammatic representations through Bar diagrams, Pie diagram, Histogram, Frequency polygon
- Understand measures of central tendency, viz., Mean, Median and Mode in series of individual observations.
- Workout simple problems in discrete and continuous series.
- Analyze measures of dispersion namely range, quartile deviation, Mean deviation about an mean, standard deviation and co-efficient of variation for individual, discrete and continuous type data.
- Distinguish different types of correlation
- Calculate Karl Pearson's correlation coefficient for a lot of problems
- Thoroughly understand and analyze the given problems with the standard regression types.
- Compute partial and multiple regression coefficient for a plenty of problems.

GENERAL INTELLIGENCE

Course Code: 21M05UEC
Prerequisite: Nil

L	T	P	C
2	1	0	2

Objectives.

- To gain quantitative aptitude required in the present scenario.
- To emphasize the right perceptive needed to crack such problems and understand the recurring pattern in those problems.

Unit-I. Problems on Numbers- Average-Problems on Ages.

Unit-II. Percentage-Profit & Loss-Simple Interest-Compound Interest.

Unit-III. Ratio & Proportion-Partnership-Calender-Clocks.

Unit-IV. Time and work-Pipes & Cistern

Unit-V. Time & Distance-Problems on Trains-Boats and Streams

Unit-VI (Advanced topics only for discussion). Current Contours: Simple problems using sets, functions, group theory etc.

Text book(s): Dinesh Khattar, The Pearson Guide To Quantitative Aptitude For Competitive Examinations, Pearson Education, 3 edition, 2015.

Course Outcomes:

Students will be able to

- Face competitive examinations with confidence.
- Solve a lot of problems on numbers and averages and problems on ages.
- Get a lot of training on percentage, profit and loss.
- Crack problems on calculating simple interest and compound Interest.
- Work on a plenty of problems on time and work.
- Get working knowledge on ratios and proportions.
- Calculate time, distance, speed given the other two and solve lot of problems
- Acquire problem solving ideas on trains, boats and streams.

VALUE ADDED COURSES
INTRODUCTION TO LATEX

Course Code:21M01VAC
Prerequisite: Nil

L	T	P	C
1	0	1	2

Objectives.

- To make the students learn the art of typing mathematics text on their own.
- To inculcate professional training required to become a scholar in mathematics

Unit-I. Basic Structure of Latex 2e - Input file structure - Layout -Editors - Forward Search - Inverse Search -Compling - Conversion to various formats.

Unit-II. Typesetting simple documents - sectioning - Titles- page layout -listing -enumerating - quote -letter formats

Unit-III. Using package amsmath typing equations labeling and refreing

Unit-IV. Figure inclusion - Table inclusion

Unit-V. Bibliography - Index typing - Beamer presentation Styles

Unit-VI (Advanced topics only for discussion).

Current Contours: Type a mathematical article using various journal style files

Text book(s):

Leslie Lamport. LATEX: A Document Preparation System, Addison-Wesley, Read- ing, Massachusetts, second edition, 1994.

References.

(1) Tobias Oetiker, Hubert Partl, Irene Hyna and Elisabeth Schlegl., The (Not So) Short Introduction to LATEX2e, Samurai Media Limited (or available online at `http://mirrors.ctan.org/info/lshort/english/lshort.pdf`)

(2) LATEX Tutorials - A Primer, Indian TeX Users Group, available online at `https://www.tug.org/twg/mactex/tutorials/ltxprimer-1.0.pdf`

(3) H. J. Greenberg. A Simplified introduction to LATEX, available online at `https://www.ctan.org/tex-archive/info/simplified-latex/`

(4) Using Kile - KDE Documentation,`https://docs.kde.org/trunk4/en/extragear_office/kile/quick-using.html`

(5) Amsmath and geometry package available in Ctan org.

Course Outcomes:

Students will be able to

- Students can type their own mathematical article/notes/book/journal paper/project work.
- Will motivate them to meticulously prepare their own mathematical notes.
- Able to understand basic structure of Latex 2e and conversions of them to various formats.
- Able to typeset and compile documents with titles, sectioning and enumeration etc.
- Use various style files and in particular amsmath, amsfonts, amsthm.

- Understand how to align math equations, matrices etc.
- Include the figures in various formats into their latex document and compile it sucessfully
- Utilize bibtex feature of including bibliographies and indexes.

INTRODUCTION TO SAGEMATH

Course Code: 21M02VAC
Prerequisite: Nil

L	T	P	C
1	0	1	2

Objectives.

- To learn one of the powerful open source software
- To visualize the mathematical concepts
- To train the students to become a professional mathematician

Unit-I. Using sagemath as a advanced engineering calculator. Evaluation of elementary functions (polynomials, square root, trigonometric, exponential, logarithmic etc) Basic usage in Combinatorcs & Number theory

Unit-II. Plotting : simple plots of known functions, polar plotting, plotting implicit functions, contour plots, level sets, parametric 2D plotting, vector fields plotting, gradients.

Unit-III. Advanced plotting 3D plots

Unit-IV. Basic usages in Linear Algebra and Vector Calculas

Unit-V. Basic usage in Real Analysis and Algebra

Unit-VI (Advanced topics only for discussion).

Current Contours: Learning advanced computing in topics selected areas like numerical analysis, linear algebra, number theory, coding theory, cryptography, graph theory.

Text book(s):

Gregory V. Bard. Sage for Undergraduates, American Mathematical Society, available online at `http://www.gregorybard.com/Sage.html`

References.

(1) Tuan A. Le and Hieu D. Nguyen. SageMath Advice For Calculus available online at `http://users.rowan.edu/~nguyen/sage/SageMathAdviceforCalculus.pdf`

Course Outcomes:

Students will be able to

- Students will be comprehend the theoretical concept and visualize them in much more better way.
- Plotting tools helps students to get easier plots and include it in their project cum paper work.
- Evaluate elementary functions such as polynomials, square root, trigonometric, exponential, logarithmic etc
- Work on basic number theoretic concepts such as checking whether a number is prime, performing congruences etc.
- Attain mastery in various 2d and 3d plots, viz., simple plot, polar plot, implicit plot etc.
- Use the plotting ideas and others to work on basic real analysis problems.
- Gain expertise on the computations involving matrices and linear algebra in general.
- Compute the basic group theoretic examples in algebra.

Introduction to Python Programming

Course Code:21M03VAC
Prerequisite: Nil

L	T	P	C
1	0	1	2

Objectives.

- To learn the basics of scientific computing through Python Programming.
- To inculcate professional training in algorithmic approach of Problem Solving.

Unit-I. Review of Linux commands; File management and permissions; Using VI editor; Introducing a programming language, syntax, basic tools, simple programmes, etc.

Unit-II. Basic Tools; First Program file; Handling complex numbers; Functions and loops; Standard math functions; Conditionals; Python keywords and finction names; Defining Names;

Unit-III. Lists in Python;Defining and accessing lists; Loops with lists; Range function; for loop with lists for sorting; Built-in sort functions; else class in loops; slicing lists; lists as stacks; using lists as queues; new lists from old;

Unit-IV. Data types; Numeric Types; Tuples; Accepting tuple inputs; sorting iterables; the lambda function; Sets; Dictionaries; Input and output; Output formatting; Format specifiers; align, sign, width, precision, type; File operations; Functions from Numpy and Scipy libraries.

Unit-V. Math problems for practice which includes the following:
(a) Finding GCD of two or more integers;
(b) Primality checking; Finding primes upto a given integer;
(c) Plotting curves;
(d) Area of a triangle;
(e) Angle between vectors;
(f) Convert a number in decimal to a given base n.
(g) Transpose of a matrix; Product of two matrices;
(h) Finding the mean; median; mode; standard deviation etc., of a given data;

Unit-VI (Advanced topics only for discussion). Current Contours: Object Oriented Programming
Text book(s): Real Python, A Practical introduction to Python, `https://static.realpython.com/python-basics-sample-chapters.pdf`

References.

(1) Qingkai Kon et all, Python Programming and Numerical Methods - A Guide for Engineers and Scientists, `https://pythonnumericalmethods.berkeley.edu/notebooks/Index.html`
(2) Brian Heinold, A Practical Introduction to Python Programming `https://www.brianheinold.net/python/A_Practical_Introduction_to_Python_Programming_Heinold.pdf`

Course Outcomes:

Students will be able to

- Students can comprehend Python Programming and basic commands.
- Will make them learn basic tools, functions and loops.
- Students will get expertise in Standard math functions
- Able to understand basic various formats of listing.
- Able to get expertise in various data types .
- Use of Numeric types and Tuples will be at ease.
- Students will lean various type of File operations and use standard libraries
- Simple programs will make them confident in learning the algorithmic approach of problem solving.

SAGEMATH FOR ABSTRACT ALGEBRA

Course Code: 21M04VAC
Prerequisite: Nil

L	T	P	C
1	0	1	2

Objectives.

- To learn one of the powerful open source software for Algebra in particular
- To visualize the mathematical concepts
- To appreciate the applications of computer algebra system (CAS)

Unit-I. Groups -subgroups - Permutations - Lagrange's theorem

Unit-II. Basic cryptography - isomorphism - Normal subgroups - factor groups.

Unit-III. Structure of groups - group action - The sylow theorems

Unit-IV. Rings - Polynomial - Integral domains - Lattices

Unit-V. Vector spaces -fields -finite fields -Galois theory

Unit-VI (Advanced topics only for discussion).

Current Contours: Learning advanced computing in topics selected areas like numerical analysis, linear algebra, number theory, coding theory, cryptography, graph theory.

Text book(s):

(1) Ajit Kumar, Vikas Bist, Group Theory An expedition with Sage Math, Narosa Publications, New Delhi, 2021
(2) Sage for Abstract Algebra, Robert Beezer, Avalialbe online at `abstract.ups.edu/download/aata-20111223-sage-4.8.pdf`

References.

Course Outcomes:

Students will be able to

- Students will be comprehend the theoretical concept and visualize them in a much more better way.
- Understand how to code various groups and subgroups.
- Evaluate the order of various elements in a permutation group
- Work on basic problems in normal subgroups and homomorphism theorems.
- Attain mastery in group actions through CAS
- Use the programming idea to code Rings and lattices.
- Gain expertise on the computations involving matrices and linear algebra in general.

INTRODUCTION TO R PROGRAMMING

Course Code:21M05VAC
Prerequisite: Nil

L	T	P	C
1	0	1	2

Objectives.

- To make the students learn the art of R Programming.
- To inculcate professional training required to understand basic statistical programming

Unit-I. Introduction to R Langauage - Basic commands - Data slicing

Unit-II. Importing and Exporting Data - Creating Frequency Distribution - Relative Frequency Distribution.

Unit-III. Plots: Bar - Pie Chart -Boxplot - Histogram

Unit-IV. Descriptive Statistics using R

Unit-V. Correlation Analysis -T-Test - Bivariate Regression -Multiple Regression

Unit-VI (Advanced topics only for discussion).

Current Contours: Applications to Data Science.

Text book(s):

W. John Braun and Duncan J. Murdoch, A First Course in Statistical Programming with R, Cambridge University Press, Newyork, 2007

References.

(1) J H Maindonald, Using R for Data Analysis and Graphics: Introduction, Code and Commentary, 2008, `https://cran.r-project.org/doc/contrib/usingR.pdf`

(2) Kim Seefeld and Ernst Linder, Statistics Using R with Biological Examples, `https://cran.r-project.org/doc/contrib/Seefeld_StatsRBio.pdf`

Course Outcomes:

Students will be able to

- Students can comprehend R language and basic commands.
- Will motivate them to meticulously explore data tools.
- Students will get expertise in creating Frequency distributions
- Able to understand basic various formats of plotting.
- Able to get expertise in comparing various statistical diagrams.
- Use various descriptive statistical methods.
- Understand Correlation Analysis through R programming.
- Analyze the figures obtained through Bivariate Regression.

QUANTITATIVE APPTITUDE

Course Code:21M06VAC
Prerequisite: Nil

L	T	P	C
1	0	1	2

Objectives.

- To gain quantitative aptitude required in the present scenario.
- To emphasize the right perceptive needed to crack such problems and understand the recurring pattern in those problems.

Unit-I. Problems on Numbers- Average-Problems on Ages.

Unit-II. Percentage-Profit & Loss-Simple Interest-Compound Interest.

Unit-III. Ratio & Proportion-Partnership-Calender-Clocks.

Unit-IV. Time and work-Pipes & Cistern.

Unit-V. Time & Distance-Problems on Trains-Boats and Streams.

Unit-VI (Advanced topics only for discussion).

Current Contours: Simple problems using sets, functions, group theory etc.

Text book(s):

Dinesh Khattar, The Pearson Guide To Quantitative Aptitude For Competitive Examinations, Pearson Education, 3 edition, 2015.

Course Outcomes:

Students will be able to

- Face competitive examinations with confidence.
- Solve a lot of problems on numbers and averages and problems on ages.
- Get a lot of training on percentage, profit and loss.
- Crack problems on calculating simple interest and compound Interest.
- Work on a plenty of problems on time and work.
- Get working knowledge on ratios and proportions.
- Calculate time, distance, speed given the other two and solve lot of problems.
- Acquire problem solving ideas on trains, boats and streams.