Dissemination of Education for Knowledge, Science and Culture"
- Shikshanmaharshi Dr. Bapuji Salunkhe

Shri Swami Vivekanand Shikshan Sanstha's

Vivekanand College, Kolhapur (Autonomous)

DEPARTMENT OF MATHEMATICS

M.Sc. Part - II
Semester-II & IV

SYLLABUS

Under Choice Based Credit System

to be implemented from Academic Year 2022-23

M.Sc. II (Sem -III and IV) Mathematics
Course Structure
Semester III

Paper No.	Course code	Title of Old Paper	Title of New Paper	Percentage of Change (%)	No. of Credits
I	CC-1180C	Functional Analysis	Functional Analysis	**0**	5
II	CC-1181C	Advanced Discrete Mathematics	Advanced Discrete Mathematics	0	5
III	CBC-1182C	Number Theory	Lattice Theory-I	100	5
IV	CBC-1183C	Graph Theory	Number Theory	100	5
V	CBC-1184C	Operational Research-I	Operational Research-I	0	5
VI	CBC-1185C	Lattice Theory--I	Fuzzy Mathematics -I	**100**	5
VII	CBC-1186C	Dynamical System -I	Dynamical System -I	0	5
VIII	CBC-1187C	Commutative Algebra	Commutative Algebra	0	5

Semester IV

Paper No.	Course code	Title of Old Paper	Title of New Paper	Percentage of Change (%)	No. of Credits
I	CC-1190D	Field Theory	Field Theory	0	5
II	CC-1191D	Integral Equations	Measure and integration	100	**5**
III	CBC-1192D	Algebraic Number Theory	Algebraic Number Theory	0	**5**
IV	CBC-1193D	Graph Theory II	Fuzzy Mathematics -II	100	**5**
IV	CBC-1194D	Operational Research II	Operational Research-II	0	**5**
V	CBC-1195D	Fluid Dynamic	Introduction to Data Science	100	**5**
VI	CBC-1196D	Dynamical System II	Dynamical System-II	**0**	**5**
VII	CBC-1197D	Combinatorics	Combinatorics	**0**	**5**
VIII	CBC-1198D	Fractional Differential Equation	Fractional Calculus	**0**	**5**

M.Sc. Mathematics Part – II CBCS
Semester - III Paper- I
Functional Analysis (CC-1180C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 To familiarize the students with the fundamental topics, principles and methods of functional analysis

CO2 Understand and apply fundamental theorems from the theory of normed and Banach spaces, including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem.

CO3 Able to understand Hilbert space and its application and acquire knowledge of orthogonal sets and operators

CO4 Understand Adjoint of an operator on a Hilbert space and concept of projection, self – adjoint, normal and unitary operator.

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	Normed linear spaces, Banach spaces, Quotient spaces, Continuous linear transformations, Equivalent norms, Finite dimensional normed spaces and properties, Conjugate space and separability, The Hahn-Banach theorem and its consequences**.**	15	1
Module 2	Second conjugate space, the natural embedding of the normed linear space in its second conjugate space, Reflexivity of normed spaces, Weak * topology on the conjugate space. The open mapping theorem, Projection on Banach space, the closed graph theorem, the conjugate of an operator, the uniform boundedness principle.	15	2
Module 3	Hilbert spaces: examples and elementary properties, Orthogonal complements, The projection theorem, Orthogonal sets, The Bessel's inequality, Fourier expansion and Parseval's equation, separable Hilbert spaces, The conjugate of Hilbert space, Riesz's theorem, The adjoint of an operator.	15	1
Module 4	Self adjoint operators, Normal and Unitary operators, Projections, Eigen values and eigenvectors of an operator on a Hilbert space, The determinants and spectrum of an operator, The spectral theorem on a finite dimensional Hilbert space.	15	1

Reference Books:

1. Erwin Kreyszig: Introductory Functional Analysis with Applications, John Wiley and Sons, 1978
2. G. Bachman and L. Narici: Functional Analysis, Academic Press, 1972.
3. A. E. Taylor: Introduction to Functional analysis, John Wiley and sons,1958.
4. J. B. Convey, A course in Functional Analysis, Springer-Verlag, 1985.
5. B. V. Limaye: Functioned Analysis, New age international, 1996

M.Sc. Mathematics Part – II CBCS
Semester - III Paper- II
Advanced Discrete Mathematics (CC-1181C)
Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Solve discrete probability problems and use set to solve problems in combinatorics and probability theory.

CO2 Determine if a given graph is simple or a multigraph, directed or undirected graph, cyclic or acyclic, and determine the connectivity of a graph.

CO3 To determine if graph has a Euler or a Hamiltonian path or circuit, Define Pigeonhole principle and solve problems related to this.

CO4 Identify the types of Lattices and find supremum and infimum.

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Graph Theory: Definition, examples and properties, Simple graph, Graph isomorphism, Bipartite graphs, Complete Bipartite graph, regular graph, sub-graphs spanning sub-graph, Edge deleted sub-graph, Vertex deleted sub-graph, Union and intersection of two graphs, complements of a graph, self-complementary graph, paths and cycles in a graph, Eccentricity, radius and diameter of a connected graph, Peterson graph, Wheel graph. Isomorphism of Graphs. First theorem of graph theory.	15	2
Module 2	The Matrix representation of a graph, Adjacency matrix and Incidence matrix of a graph, Definition and simple properties of a tree, bridges, spanning trees, Inclusion exclusion principle. Simple examples on Inclusion exclusion principal Pigeonhole principle, examples on Pigeonhole principle.	15	1
Module 3	Discrete numeric functions and sum and product of two numeric functions, generating functions, Linear recurrence relations with constant coefficients Particular solutions of linear recurrence relations, Total solutions.	15	1
Module 4	Ordered sets and lattices Hasse diagrams of posets, Supremum and infimum, Isomorphic ordered sets, well-ordered sets, Lattices, Bounded lattices, Distributive lattices, Complements complemented lattices, Boolean algebra, Basic definitions, Basic theorems, duality, Boolean algebras as lattices	15	1

Reference Books:

1. Lipschitz and Mark Lipson: Discrete Mathematics (second edition) , Tata McGraw Hill Publishing Company Ltd. New Delhi
2. Gorrett Birkhoff : Lattice Theory 2. Rich and Brualdi : Combinatoric
3. John Clark and Derek Holton: A first book at Graph Theory Applied Publishers Ltd.

4. C. T. Liu: Discrete Mathematics

M.Sc. Mathematics Part – II CBCS
Semester - III Paper- III
Lattice Theory-I (CBC-1182C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Understand the relation between posets and lattices
CO2 Study the basic properties and characterization of lattice
CO3 Understand and apply the distributive complemented lattice
CO4 Design analyze and implement the concepts of stone's theorem and its consequence, pseudo complemented lattices and it's dual

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	Basic concepts. Posets, Definition and examples of posets. Two definitions of lattices and their equivalence, examples of lattices. Description of Lattices, some algebraic concepts. Duality principle, Special elements. Homomorphism, Isomorphism and isotone maps.	15	1
Module 2	Special types of Lattices. Distributive lattices – Properties and characterizations. Modular lattices – Properties and characterizations. Congruence relations. Boolean algebras – Properties and characterizations.	15	1
Module 3	Ideal theory, Ideals and filters in lattices. Lattice of all ideals I(L). Properties and characterizations of I(L). Stone's theorem and its consequences..	15	1
Module 4	Stone algebra, Pseudo complemented lattices. S(L) and D(L) – special subsets of pseudo complemented lattices. Distributive pseudo complemented lattice. Stone lattices – properties and characterizations	15	2

Reference Books:

1. George Gratzer : General lattice theory, Academic Prress publications, 1978
2. B. V. Davey and H. A. Priestley: Introduction to Lattices and Order, Cambridge University Press, Second edition, 2002.
3. Lattice theory by G. Birkhoff, Amer. Math. Soc. Coll. Publications, Third Edition 1973

M.Sc. Mathematics Part – II CBCS
Semester - III Paper -IV
Number Theory (CBC-1183C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Learn more advanced properties of primes and pseudo primes.
CO2 Able to apply Mobius Inversion formula to number theoretic functions.
CO3 Able to explore basic idea of cryptography.
CO4 Understand concept of primitive roots and index of an integer relative to a given primitive root.

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Review of Divisibility: The division algorithm, G.C.D., Euclidean algorithm, Diophantine equation $ax + by = c$, Primes and their distribution: Fundamental theorem of arithmetic, The Goldbach Conjecture.	15	1
Module 2	Congruences: Properties of congruences, Linear congruences, Chinese Remainder Theorem Special divisibility tests, Fermat's theorem, Wilsons's theorem and applications	15	1
Module 3	Number Theoretic Functions: Euler's phi function, Euler's theorem, Greatest integer function, the functions $\tau$and σ, Mobius function and Mobius inversion formula, Properties of these functions and their inter relations.	15	1
Module 4	Primitive roots: The order of an integer modulo n, Primitive roots of primes, composite numbers having primitive roots, The theory of indices, The quadratic reciprocity law: Eulerian criteria, The Legendre symbol and its properties, quadratic reciprocity, quadratic reciprocity with composite moduli.	15	2

Reference Books:

1. D. M. Burton: Elementary Number Theory, Universal book stall, New Delhi.
2. S. B. Malik: Basic Number theory Vikas publishing House
3. George E. Andrews: Number theory, Hindustan Pub. Corp. (1972)
4. Niven, Zuckerman: An Introduction to theory of numbers. John Wiley & Sons
5. S. G. Telang, Number Theory, Tata Mc. Graw-Hill Publishing Co., New Delhi

M.Sc. Mathematics Part – II CBCS

Semester - III Paper-V

Operational Research -I (CBC-1184C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Able to identify convex set and convex functions and construct linear integer programming models discuss the solution techniques

CO2 Solve multi –level decision problems using dynamic programming method.

CO3 Identify the appropriate methods to solve the different kinds of Optimization Problems.

CO4 Formulate the nonlinear programming models and able to find solution methods for solving the nonlinear and linear optimization problems.

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Convex sets and their properties. Lines and hyper planes convex set Important Theorems, polyhedral convex set, convex combination of vectors, convex hull, convex polyhedron, convex cone, simplex and convex function, General formulation of linear programming Matrix form of LP problem, definitions of standard LPP., Fundamental Theorem of linear programming.	15	1
Module 2	Simplex method, computational procedure of simplex method, problem of degeneracy and method to resolve degeneracy. Revised simplex method in standard form I, Duality in linear programming duality theorems, Integer linear programming, Gomory's cutting plane method, Branch and Bound method.	15	2
Module 3	Dynamic programming. Bellman's principle of Optimality, solution of problems with a finite number of stages. Application of dynamic programming in production, inventory control and linear programming.	15	1
Module 4	Nonlinear programming unconstrained problems of maximum and minimum Lagrangian method Kuhn Tucker necessary and sufficient conditions, Wolfe's method, Beale's method.	15	1

Reference Books:

1. S. D. Sharma: Operations Research, Kedar Nath Ram Noth and co
2. Kanti Swarup,P. K. Gupta and Manmohan : Operations research, S. Chand& Co.
3. Hamady Taha: Operations Research: Mac Millan Co.
4. S. D. Sharma: Nonlinear and Dynamic programming KedarNath Ram Nath and Co. Meerut
5. R. K. Gupta: Operations Research Krishna Prakashan Mandir, Meeru
6. G. Hadley: Linear programming, Oxford and IBH Publishing Co.

M.Sc. Mathematics Part – II CBCS
Semester - III Paper-VI
Fuzzy Mathematics-I (CBC-1185C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Acquire the knowledge of notion of crisp sets and fuzzy sets
CO2 Understand the basic concepts of crisp set and fuzzy sets
CO3 Develop the skill of operation on fuzzy sets and fuzzy arithmetic's
CO4 Demonstrate the technologies of fuzzy sets and fuzzy numbers

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	Fuzzy sets and crisp sets, examples of fuzzy sets, types of fuzzy sets, standard operations, cardinality, degree of subset hood, level cuts and its properties, representation of fuzzy sets, decomposition theorems, extension principle, properties of direct and inverse images of fuzzy sets	15	2
Module 2	Operations on fuzzy sets, types of operations, fuzzy complement, equilibrium and dual point Increasing and decreasing generators, fuzzy intersection: t-norms.	15	1
Module 3	Fuzzy union t-conorms, characterization theorem of t-conorm, combination of operators, aggregation operations, ordered weighted averaging operations.	15	1
Module 4	Fuzzy numbers, characterization theorem, linguistic variables, arithmetic operations on intervals, arithmetic operations on fuzzy numbers, lattice of fuzzy numbers, fuzzy equations	15	1

Reference Books:

1. George J. Klir, Bo Yuan, Fuzzy sets and Fuzzy Logic. Theory and Applications, PHI, Ltd.2000
2. M. Grabish, Sugeno, and Murofushi Fuzzy Measures and Integrals: Theory and Applications, PHI, 1999
3. H.J.Zimmerermann, Fuzzy Set Theory and its Applications, Kluwer, 1984.
4. M. Hanss, Applied Fuzzy Arithmetic, An Introduction with Engineering Applications, Springer- Verlag Berlin Heidelberg 2005.
5. M. Ganesh, Introduction to Fuzzy Sets & Fuzzy Logic; PHI Learning Private Limited, New Delhi 2011.
6. Bojadev and M. Bojadev, Fuzzy Logic and Application, World Scientific Publication Pvt.Ltd. 2007

M.Sc. Mathematics Part – II CBCS

Semester - III Paper-VII

Dynamical System -I (CBC-1186C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Classify equilibrium points of the dynamical system

CO2 Construct bifurcation diagrams and analyze the system for different values of parameter.

CO3 Relate the qualitative properties of the system with the eigen values of coefficient matrix.

CO4 Construct the exponential of a matrix and apply it to solve the dynamical system.

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	First order systems- Qualitative Analysis: Introduction: First order linear systems, equilibrium points- classification, stability, bifurcation, phase portraits, Scalar autonomous non- linear systems, Stability (linearization, equilibrium points), phase portraits- slope fields, Examples, two-parameter family.	15	1
Module 2	Planer systems- Qualitative Analysis, Second order linear ODE as a system of first order ODEs, preliminaries from algebra, eigenvalues and eigenvectors, solution of planar linear systems, Phase portraits for planar systems: Real distinct eigenvalues, complex eigenvalues, repeated eigenvalues, changing co-ordinates, Classification of planar systems: the trace-determinant plane	15	2
Module 3	Higher order systems: Preliminaries from linear algebra, Higher order ODEs as a vector differential equation, real distinct, complex and repeated eigenvalues, The Exponential of a Matrix, Solving a system of first order differential equations by using exponential of a matrix, Non-autonomous systems of the form $X'(t) = AX(t) + G(t)$, Variation of parameters.	15	1
Module 4	Discrete dynamical systems: Introduction to the discrete maps (iterative maps), orbit, periodic points, cobweb plots, Fixed points of a map, stability analysis of a fixed point (sink, source, saddle), Bifurcation and chaos: Standard examples (Logistic map, tent map, doubling map).	15	1

Reference Books:

1. M. Hirsch, S. Smale and R. L. Devaney : Differential equations, dynamical

systems, and an introduction to chaos , Elsevier Academic Press, USA, 2004

M.Sc. Mathematics Part – II CBCS
Semester - III Paper-VIII
Commutative Algebra (CBC-1187C)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Classify the ideals to solve the related problems.
CO2 Understand various radicals and know Hilbert basis theorem and apply it to other development
CO3 Use Nakayama Lemma for further development in Noetherion Rings.
CO4 Derive the Krull intersection theorem.

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Rings and ring homomorphism, Ideals. Quotient rings, Zero divisors. Nilpotent elements. Units, Prime ideals and Maximal ideals, Nilradicals and Jacobson radical, Operations on ideals, Extension and contraction	15	1.5
Module 2	Modules and modules homomorphisms, Submodules and quotient modules , Operations On submodules ,Direct sum and product ,Finitely generated modules ,Exact sequences	15	1.5
Module 3	Tensor product of modules , Restriction and extension of scalars , Exactness properties Of the tensor product , Algebras of tensor products	15	1
Module 4	Rings and modules of fractions, Local properties , Extended and contracted ideals in rings of fractions , primary decomposition	15	1

Reference Books:

1. M. F. Atiyah and I. G. MacDonald – Introduction to commutative Algebra, Addison Wesley publishing company
2. M.D. Larsen and P. J. McCarthy ; Multiplicative theory of ideals, Academic press,1971
3. D.G. Nortcot Ideal theory, Cambridge University press,1953

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-I
Field Theory (CC-1190D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Apply the knowledge of algebra to attain a good mathematical maturity and enables to build mathematical thinking and reasoning

CO2 Identify and analyse different types of algebraic structures such as algebraically closed fields, splitting fields, finite field extension to understand and use the fundamental results in Algebra

CO3 Design analyse and implement the concepts of Gauss lemma, separable extension etc.

CO4 Identify the challenging problems in advanced algebra to pursue further research

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	Field Extensions Extension of a field, Algebraic extensions, algebraically closed fields, Derivatives and multiple roots, Finite Fields	15	1
Module 2	Galois Theory Separable and normal extensions, Automorphism groups and fixed fields, Fundamental theorem of Galois theory	15	1.5
Module 3	Finite Fields Prime fields, Fundamental theorem of algebra, Cyclic extensions, Cyclotomic extensions	15	1
Module 4	Applications of Galois theory Constructions by ruler and compass, Solvable groups, Polynomials solvable by radicals	15	1.5

Reference Books:

1. U. M. Swamy, A. V. S. N. Murthy, Algebra: Abstract and Modern, Pearson Education, 2012
2. Nathan Jacobson, Basic Algebra I, second edition, W. H. Freeman and company, New York
3. M. Artin, Algebra, PHI, 1996.
4. N. Herstein, Topics in Algebra, Wiley Eastern Ltd.
5. Bhattacharya, Jain and Nagpal, Basic Abstract Algebra, 2nd edition, Narosa Publishing House, New Delhi
6. John Fraleigh : A first course in Abstract Algebra (3rd edition) Narosa publishing house, New Delhi.

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-II
Measure and Integration (CC-1191D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Understand algebra of sets, open and closed sets of real number and outer measure and measurable sets

CO2 Understand the abstract measure theory and definition and main properties of the integral

CO3 Able to construct Lebesgue's measure on the real line and in n-dimensional Euclidean space.

CO4 Able to use the concept of measure theory to solve the problems related to probability theory, stochastic calculus and functional analysis

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	Open Sets, Closed Sets and Borel Sets, Lebesgue Outer Measure, The sigma algebra of Lebesgue Measurable Sets, Countable Additivity, Continuity and Borel-Cantelli Lemma, non- measurable set.	15	1
Module 2	Sums, Product and Composition of Measurable Functions, Sequential Pointwise limits and Simple Approximation. Littlewood's Three Principles, Egoroff's Theorem and Lusin's Theorem, Lebesgue Integration of a Bounded Measurable Function, Lebesgue Integration of a Non-negative Measurable Function.	15	1.5
Module 3	The General Lebesgue Integral, Characterization of Riemann and Lebesgue Integrability, Differentiability of Monotone Functions, Lebesgue's Theorem, Functions of Bounded Variations: Jordan's Theorem.	15	1
Module 4	Absolutely Continuous Functions, Integrating Derivatives: Differentiating Indefinite Integrals, Normed Linear Spaces, Inequalities of Young, Holder and Minkowski, The Riesz-Fischer Theorem.	15	1.5

Reference Books:

1. Royden H. L., Fitzpateick P.M., Real Analysis. (2009) 4th edition. Prentice Hall of India, New Delhi
2. G. deBarra. Measure Theory and Integration. (1981) Wiley Eastern Ltd.
3. Rana, I. K. An Introduction to Measure and Integration. (1997) Narosa Book Company.
4. Berberian, S. K. Measure and Integration. (1965) McMillan, New York.
5. Jain P. K. and Gupta V. P. ,Lebesgue measure and Integration, (1986), Wiley Easter

Limited.

6. Rudin W., Principles of Mathematical Analysis, (1964) McGraw-Hill Book Co

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-III
Algebraic Number Theory (CC-1192D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Understand The concept (definition and significance) of algebraic numbers and algebraic integers.

CO2 Understand and clearly define number fields and their ring of integers, in particular quadratic number fields and cyclotomic number fields.

CO3 Able to factorize an algebraic integer into irreducible and find the ideals of an algebraic number ring.

CO4 Able to compute the class groups and the group of units of a number field.

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	Revision of rings, polynomial rings and fields, Field extensions, Symmetric polynomials, Modules, Free Abelian groups.	15	1
Module 2	Algebraic Numbers, Algebraic number fields, Conjugates and Discriminants, Algebraic integers, Integral Bases, Norms and Traces, Ring of integers, Quadratic fields, Cyclotomic fields.	15	1.5
Module 3	Factorization into irreducible, Noetherian rings, Dedekind rings, Examples of Non- Unique factorization into irreducible, Prime factorization, Euclidean Domains, Euclidean quadratic fields.	15	1
Module 4	Ideals, Prime factorization of ideals, Norm of an ideal, Nonunique factorization in cyclotomic fields, Two-squares theorem, Four-squares theorem, class groups and class numbers, Finiteness of the Class groups .	15	1.5

Reference Books:

1. I.N. Stewart & D.O. Tall, Algebraic Number Theory , Academic press.
2. N. Jacobson, Basic Algebra - I, Hindustan Publishing Corporation (India), Delhi.
3. P. Samuel, Algebraic Theory of Numbers, Hermann, Paris (1970).
4. Mathematical Pamphlet, Algebraic Number Theory,TIFR, Bombay.
5. Paulo Ribenboim, Classical Theory of Algebraic Numbers, Springer, New York (2001).
6. N.S. Gopalkrishnan, University Algebra, New Age International(P) Ltd. Publishers.

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-IV
Fuzzy mathematics -II (CC-1193D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Acquire the concept of fuzzy relations
CO2 Understand the basic concepts of fuzzy logic and fuzzy algebra
CO3 Construct approximate solutions of fuzzy relation equations
CO4 Solve problems in Engineering and medicine

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Projections and cylindrical extensions, binary fuzzy relations on single set, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy ordering relations, fuzzy morphisms sup-i composition and inf-wi composition	15	1.5
Module 2	Fuzzy relation equations, problem partitioning, solution methods, fuzzy relational equations based on sup-i and inf-wi compositions, approximate solutions	15	1.5
Module 3	Fuzzy propositions, fuzzy quantifiers, linguistic hedges, inference from conditional fuzzy propositions, qualified and quantified propositions.	15	1
Module 4	Nonspecificity of Crisp Sets, Nonspecificity of Fussy Sets,Fuzziness of Fuzzy sets.	15	1

Reference Books:

1. George J Klir, Bo Yuan, Fuzzy Sets and Fuzzy Logic. Theory and applications, PHI.Ltd. (2000).
2. M. Grabish, Sugeno, and Murofushi, Fuzzy Measures and Integrals: Theory and Applications PHI,1999
3. John Mordeson, Fuzzy Mathematics, Springer,2001
4. H.J. Zimmerermann, Fuzzy set: Theory and its Applications, Kluwer, 1984.
5. M. Ganesh : Introduction to Fuzzy sets & Fuzzy Logic; PHI Learning Private Limited, New Delhi,2011.

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-V
Operational Research -II (CC-1194D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Decide an optimal replacement period/policy for a given item/equipment/machine

CO2 Understand the various selective inventory control techniques and its applications. Capability to develop deterministic inventory models

CO3 Understand the mathematical modeling of queuieng systems To apply and extend queueing models to analyze real world systems.

CO4 Understand application of PERT and CPM techniques and able to construct network diagrams

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Replacement Problems, Failure mechanism of items, Replacement policy for items whose maintenance cost increases with time and money values is constant, Group replacement of items that fail completely	15	1
Module 2	Inventory – Cost involved in inventory problems, variables in inventory problem, symbols in inventory concept of EOQ, Methods with calculus method ,Model I (a) The economiclot size system with uniform demand, Model I (b) Economic lot size with different rates of demand in different cycles.,Model I (c) Economic lot size with finite Rate of Replenishment.,(EOQ production model) EOQ model with shortages , Model II(a) The EOQ with constant rate of demand, scheduling, time constant.	15	2
Module 3	Queuing Theory, Queuing systems, Queuing Problems: transient and steady states, traffic intensity, Probability distributions in Queuing systems Poisson process, Properties, Exponential process, Classification of Queuing Models,Model I:(M/M/I) : (∞/FCFS), Model II (a) : General Erlang queuing model.	15	1
Module 4	Information Theory: Communication process, Quantitative measure of information, A binary unit of information, measure of uncertainty of entropy, basic properties of entropy function (H) Joint and conditional entropies, Uniqueness theorem, Chanel capacity, efficiency and redundancy Encoding, Shannon Fano encoding procedure, PERT / CPM: Applications of PERT /CPM techniques, Network diagram, representations. Rules for constructing the	15	1

	Network diagram, determination of the critical path		

Reference Books:

1. S.D.Sharma : Operations Research Kedarnath and co. 1999.
2. KantiSwarup ,P.K.Gupta and Manmohan : Operations research, S.Chand& Co.
3. HamadyTaha : Operations Research :Mac Millan Co.
4. R.K.Gupta : Operations Research Krishna PrakashanMandir, Meerut

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-VI
Introduction to Data Science (CC-1195D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Having an ability to apply mathematics and science in AI and machine learning applications

CO2 Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

CO3 Having problem-solving ability- solving social issues and engineering problems

CO4 Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Data science in a big data world : Benefits and uses of data science and big data, Facts of data, The data science process, The big data ecosystem and data science The data science process : Overview of the data science process, Retrieving data, Cleansing, integrating, and transforming data, Exploratory data analysis	15	2
Module 2	Machine learning: What is the machine learning, The modelling process, Types of machines learning, Semi-supervised learning	15	1
Module 3	Handling large data: General technique for handling large volume data, General programming tips for dealing with large data sets, Case study predicting malicious URLs	15	1
Module 4	First step in big data: Distributing data storage and processing with frameworks, Case study: Assessing risk	15	1

Reference Books:

1. Davy Cielen, Arno D. B. Meysman, Mohmed Ali, Introduction to data science, Manning Publications Co., 1st edition, 2016
2. Trevor Hastie, Robert Tibshirani An Introduction to Statistical Learning: with Applications in R, Gareth James , Springer, 1st edition, 2013
3. Ethem Alpaydin, Introduction to Machine Learning,Third Edition 2018 PHI Learning Private Limited

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-VII
Dynamical System II (CC-1196D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Test for the existence and uniqueness of solution of nonlinear system.
CO2 Relate the stability of the system with its linearization.
CO3 Distinguish between stable and unstable sets corresponding to the given system.
CO4 Identify the chaotic behavior in the system by using Lyapunov exponents.

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Basic concepts of nonlinear dynamics: Introduction, Historical developments, Autonomous system of nonlinear ODEs: fundamental existence and uniqueness of solution, dependence of solution on initial conditions and parameters, The maximal interval of existence.	15	1
Module 2	Stability analysis: The flow defined by a differential equation, Linearization, Stable manifold theorem, Hartman Grobman theorm, Stability and Lyapunov functions, Bifurcation.	15	1
Module 3	II Chaos: Concept, properties, Limit sets and attractors, Poincare-Bendixson theorem, The Poincare map, Lyapunov exponents in flows, Numerical computation of Lyapunov exponents, Examples: Lorenz system, Chua circuit, Rossler attractor, Forced oscillators, Chaos synchronization.	15	1.5
Module 4	Applications and computer experiments: Application of chaos to secure communication, Introduction to fractals, Use of computer software's to solve problems in Dynamical Systems: Solving linear and nonlinear systems, data visualization-2D and 3D plots, vector field plots, chaotic phase portraits, solving discrete systems- cobweb plots.	15	1.5

Reference Books:

1. Perko Differential Equations and Dynamical Systems, Springer, New York.
2. Alligood, Sauer and Yorke Chaos - an introduction to dynamical systems, Springer, New York.

3. M. Hirsch, Smale and R.L. Devaney Differential equations, dynamical systems, and an introduction to chaos, Elsevier Academic Press, USA, 2004.
4. Strogatz, Nonlinear dynamics and chaos, , Perseus Books, New York.
5. Wiggins, Introduction to applied nonlinear dynamics and chaos, Springer, New York.
6. Arrowsmith and Place Dynamical systems: differential equations, maps and chaotic behavior, Chapman and Hall, London. (Applications)

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-VIII
Combinatorics (CC-1197D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Students will familiar with fundamental combinatorial structures than naturally appears in various other field of mathematics.
CO2 Learn how to use those structure to represent mathematical applied questions.
CO3 Able to use generating function to solve a variety of combinatorial problems.
CO4 Identify the challenging problems in arrangement and selections.

Unit	**Syllabus**	**Lectures/ Teaching Hours**	**Credits**
Module 1	The sum Rule and the product Rule, Permutations and combinations, The Pigeonhole Principle, Ramsey Numbers, Catalan Numbers, Stirling Numbers.	15	1
Module 2	Generalized Permutations and combinations, Multinomial Theorem, The Inclusion – Exclusion principle, Sieve's formula, Derangements, System of Distinct Representatives (SDR), Combinatorial Number theory.	15	1.5
Module 3	Rook- Polynomial, Ordinary and Exponential generating functions, Partitions of a positive integer, Recurrence Relations, Fibonacci sequence.	15	1.5
Module 4	Group Theory in Combinatorics, The Burnside Frobenius Theorem, Permutation Groups and Their Cycle Indices, Polya's Enumeration Theorems.	15	1

Reference Books:

1. V.K. Balakrishnan Schum's Outline of Theory and problems of combinatorics. Schum's Outline
   Series Mc. Grew Hill INC
2. Alan Tucker – Applied Combinatorics. – John Willey Sons.
3. Richard A Broadly, Introductory combinatorics New Holland.
4. Sharad Sane- Combinatorial Techniques-Hindustan Book Agency

M.Sc. Mathematics Part – II CBCS
Semester – IV Paper-IX
Fractional Calculus (CC-1198D)

Theory: 60Hour **Credits -05**

Course Outcomes: After the completion of the course the student will be able to -

CO1 Understand G-L and RL-fractional integral and evaluate fractional integrals of some common functions

CO2 RL and Caputo-fractional derivatives and evaluate fractional derivatives of some common functions

CO3 To Solve Linear Fractional Differential Equation using the Laplace and Mellin transform.

CO4 The study of fractional differential

Unit	Syllabus	Lectures/ Teaching Hours	Credits
Module 1	Brief review of Special Functions of the Fractional Calculus: Gamma Function, Mittag-Leffler Function, Wright Function, Fractional Derivative and Integrals: Grünwald-Letnikov (GL) Fractional Derivatives- Unification of integer order derivatives and integrals, GL Derivatives of arbitrary order, GL fractional derivative of , Composition of GL derivative with integer order derivatives, Composition of two GL derivatives of different orders. Riemann-Liouville (RL) fractional derivatives- Unification of integer order derivatives and integrals, Integrals of arbitrary order, RL derivatives of arbitrary order.	15	1
Module 2	Composition of RL derivative with integer order derivatives and fractional derivatives, Link of RL derivative to Grünwald-Letnikov approach, Caputo's fractional derivative, generalized functions approach, Left and right fractional derivatives. Properties of fractional derivatives: Linearity, The Leibnitz rule for fractional derivatives, Fractional derivative for composite function, Riemann-Liouville fractional differentiation of an integral depending on a parameter, Behaviour near the lower terminal, Behaviour far from the lower theory.	15	1.5
Module 3	Laplace transforms of fractional derivatives- Laplace transform of the RiemannLiouville fractional derivative, Caputo derivative and Grünwald-Letnikov fractional derivative. Fourier transforms of fractional integrals and derivatives. Mellin transforms of fractional derivatives-	15	1.5

	Mellin transforms of the Riemann-Liouville fractional integrals and fractional derivative, Mellin transforms of Caputo derivative.		
Module 4	Existence and uniqueness theorem: Linear fractional differential equations (FDE), Fractional differential equation of a general form, Existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions. Methods of solving FDE's: The Laplace transform method. The Mellin transform method, Power series method.	15	1

Reference Books:

1. Igor Podlubny, Fractional differential equations. San Diego: Academic Press; 1999.
2. A. Kilbas, H.M. Srivastava, J.J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006.
3. Kai Diethelm, The Analysis of Fractional Differential Equations, Springer, 2010.

L. Debnath, D. Bhatta, Integral Transforms and Their Applications, CRC Press

SCHEME OF MARKING (THEROY)

Sem.	CC	Marks	Evaluation	Answer Books	Standard of passing
I	CC-1180C TO CBC-1187A	90	Semesterwise	As per Instruction	35% (36 marks)
II	CC-1190D TO CBC-1198D	90	Semesterwise	As per Instruction	35% (36 marks)

SCHEME OF MARKING (CIE) Continuous Internal Evaluation

Sem.	CC	Marks	Evaluation	Answer Books	Standard of passing
I	CC1180C TO CBC1187C	30	Concurrent	As per Instruction	35% (12 marks)
II	CC-1190D TO CBC-1198D	30	Concurrent	As per Instruction	35% (12 marks)

***A separate passing is mandatory**

Nature of Question Paper

Instructions: 1) Questions **No. 1** is **compulsory**.

2) Attempt any **four** questions from que. no. 2 to que. no. 7.

3) All questions carry equal marks.

4) Figures to right indicates full marks.

5) Use of log table/calculator is allowed.

Time: 3 hours **Total Marks: 90**

Q. 1. A) Choose correct alternative. (2 Marks each) **[08]**

i)

A) B) C) D)

ii)

A) B) C) D)

iii)

A) B) C) D)

iv)

A) B) C) D)

B) Fill in the blanks. (2 Marks each) **[10]**

Q.2. A) **[18]**

B)

C)

OR

A) **[18]**

B)

Q.3. A) **[18]**

B

C)

OR

A) **[18]**

B)

Q.4 A) **[18]**

B)

C)

OR

A) **[18]**

B)

Q.5. A) **[18]**

B)

C)

OR

A) **[18]**

B)

Q.6. A) **[18]**

B)

C)

OR

A) **[18]**

B)

Q.7. A) **[18]**

B)

C)

OR

A) **[18]**

B)

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……

REMARK:

Note that the distribution of marks for A, B, C or A, B (Q.N.2 to Q.N.-7)may vary according to the nature of question.