Vivekanand College,
Kolhapur

Department of Mathematics

Syllbaus for
M. Sc. Mathematics (Part-II)

Choice Based Credit System

Syllabus to be implemented from June 2019 onwards

M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2019 onwards)

Compulsory Papers

Paper	Title of Paper
CP-1180C	Functional Analysis
CP-1181C	Advanced Discrete Mathematics

Optional Papers

Paper	Title of Paper
CP-1182 C	Number Theory
CP-1183C	Graph Theory
CP-1184 C	Operations Research I
CP-1185 C	Lattice Theory –I
CP-1186 C	Dynamical Systems- I
CP-1187C	Commutative Algebra

Paper- CP1180C

Title of Paper: Functional Analysis

(iii) UNITS **No. of Lectures:**

Unit I: 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 Lectures

Unit II: 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 Lectures**

Unit III: Hilbert spaces: examples and elementary properties, Orthogonal complements, The projection theorem, Orthogonal sets, The Bessel's inequality, Fourier expansion and Perseval's equation, separable Hilbert spaces, The conjugate of Hilbert space, Riesz's theorem, The adjoint of an operator. **15 Lectures**

Unit IV: 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 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended
Book(s):

1. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw Hill, 1963.

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.

Title of Paper: CP-1181C

Title of Paper:: **Advanced Discrete Mathematics**

(iii) UNITS **No. of Lectures:**

Unit I: 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 Lectures**

Unit II: 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 principle Pigeonhole principle, examples on Pigeonhole principle. **15 Lectures**

Unit III: 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 Lectures**

Unit IV: 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 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommend Books:

1. Discrete Mathematics (second edition) by Seymon Lipschutz and Mark Lipson.Tata McGraw Hill Publishing Company Ltd. New Delhi
2. John Clark and Derek Holton : A first book at Graph Theory Applied Publishers Ltd.
3. C. T. Liu : Discrete Mathematics

Reference Books-:

1. Gorrett Birkhoff : Lattice Theory
2. Rich and Brualdi : Combinatorics

(i) Paper : CP1182C
(ii) Title of Paper: Number Theory
(iii) UNIT **No. of Lectures:**

UNIT – I
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 Lectures**

UNIT – II
Congruences: Properties of congruences, Linearcongruences, Chinese Remainder Theorem, Special divisibility tests, Fermats theorem, Wilsons theorem and applications. **15 Lectures**

UNIT – III
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 Lectures**

UNIT – IV
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 Lectures**

UNIT – V Examples, Seminars**,** Group Discussion on above four units. **15 Lectures**

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

(i) Paper : 1183C
(ii) Title of Paper: Graph Theory-I
(iii) UNIT **No. of Lectures:**

Unit 1 : Trees and connectivity: Definitions and simple properties , Bridges , spanning trees , cut vertices and connectivity , Euler tours : Euler graphs, properties of Euler graph, The Chinese postman problem, Fleury's algorithm. **[15] Lectures**

Unit 2 : Hamiltonian Cycles: Hamiltonian graph. The travelling salesman problem.Matchings : Matching and Augmenting path , The marriage problem , The personal assignment problem. **[15] Lectures**

Unit 3: The optimal assignment problem, A Chinese postman problem, Postscript Planar graph : Plane and Planar graphs, Euler formula, Platonic bodies Kurotowskis theorem. Non Hamiltonian plane graphs ,The dual of a plane graph. **[15] Lectures**

Unit 4 : Coloring : Vertex coloring , vertex coloring algorithms, critical graphs . cliques, Edge coloring, map coloring. Directed graphs :Defination, Indegree and Outdegree, Tournaments , Traffic flow. **[15] Lectures**

Unit 5 : Examples, seminars, group discussions on above four units. **[15] Lectures**

Recommended books :

1. John Clark and Derek Holton : A first llok at graph theory, Allied publishers Ltd. Bombay.

Reference books :

1. Douglas B. West : Introduction to Graph Theory Person Education Asia.
2. F. Harary – Graph Theory, Narosa publishing house (1989).
3. K.R.Parthsarthy : Basic Graph Theory,Tata McGraw Hill publishing Co.Ltd. New delhi.

(i) Paper : 1184C
(ii) Title of Paper: Operational Research –I
(iii) UNITS **No. of Lectures:**

Unit I: 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 Lectures

Unit II: 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 Lectures**

Unit III: 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 Lectures**

Unit IV: Non linear programming unconstrained problems of maximum and minimum Lagrangian method Kuhn Tucker necessary and sufficient conditions, Wolfe's method, Beale's method. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books:

1. S. D. Sharma : Operations Research, Kedar Nath Ram Noth and co

Reference Books:-

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

(i) Paper : 1185C
(ii) Title of Paper: Lattice Theory -I
(iii) UNIT **No. of Lectures:**

Unit I
Basic concepts **15 Lectures**
1. Posets, Definition and examples of posets.
2. Two definitions of lattices and their equivalence, examples of lattices.
3. Description of Lattices, some algebraic concepts.
4. Duality principle, Specialelements.
5. Homomorphism, Isomorphism and isotone maps.

Unit II
Special types of Lattices **15 Lectures**
1. Distributive lattices – Properties and characterizations.
2. Modular lattices – Properties and characterizations.
3. Congruence relations.
4. Boolean algebras – Properties and characterizations.

Unit III
Ideal theory **15 Lectures**
1. Ideals and filters in lattices.
2. Lattice of all ideals I(L).
3. Properties and characterizations of I(L).
4. Stone's theorem and its consequences.

Unit IV
Stone algebra **15 Lectures**
1. Pseudo complemented lattices.
2. S(L) and D(L) – special subsets of pseudo complemented lattices.
3. Distributive pseudo complemented lattice.
4. Stone lattices – properties and characterizations.

Unit V Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book(s):
1. Lattice theory: First concepts and distributive lattices by George Gratzer, W. H. Freeman and company, San Francisco, 1971.
2. B. V. Davey and H. A. Priestley: Introduction to Lattices and Order, Cambridge University Press, Second edition, 2002.

Reference Books:
1.Lattice theory by G. Birkhoff, Amer. Math. Soc. Coll. Publications, Third Edition 1973

(i) Paper : CP-1186C
(ii) Title of Paper: Dynamical Systems-I
(iii) UNIT **No. of Lectures:**

Unit I
First order systems- Qualitative Analysis: **15 Lectures**
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.

Unit II
Planer systems- Qualitative Analysis: **15 Lectures**
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.

Unit III
Higher order systems: **15 Lectures**
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.

Unit IV
Discrete dynamical systems: **15 Lectures**
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).

Unit V
Use of Winplot Software: **7 Lectures**
1.To draw slope fields.
2.To draw vector fields.
3.Phase-Portraits of linear and nonlinear systems in $\mathbb{R}^2$.

Unit VI Examples, seminars, group discussion on above four units. **8 Lectures**

Recommended Book:
1.Differential equations, dynamical systems, and an introduction to chaos by M. Hirsch, S. Smale and R. L. Devaney, Elsevier Academic Press, USA, 2004.

(i) Paper : CP-1187C
(ii) Title of Paper: Commutative Algebra
(iii) UNIT **No. of Lectures:**

Unit I: 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.

Unit II: Modules and modules homomorphisms, Submodules and quotient modules ,Operations On submodules ,Direct sum and product ,Finitely generated modules ,Exact sequsences.

Unit III : Tensor product of modules , Restrictionand extension of scalars , Exactness properties Of the tensor product , Algebras of tensor products.

Unit IV: Rings and modules of fractions, Local properties ,Extended and contracted ideals in rings of fractions , primary decomposition.

Recommended Books:

1. M. F. Atiyah and I. G. MacDonald – Introduction to commutative Algebra, Addison Wesley publishing company.

Reference Books:

1. M.D. Larsen and P. J. McCathy ;Multiplicative theory of ideals, Academic press,1971
2. D.G. Nortcot Ideal theory ,Cambridge University press,1953

M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2019 onwards)

Compulsory Papers

Paper	Title of Paper
CP-1190 D	Field Theory
CP-1191D	Integral Equation

Optional Papers

Paper	Title of Paper
CP-1192 D	Algebraic Number Theory
CP-1193D	Graph Theory-II
CP-1194 D	Operations Research II
CP-1195 D	Fluid Dynamics
CP-1196 D	Dynamical Systems- II
CP-1197 D	Combinatorics
CP-1198D	Fractional Differential Equations

(i) Paper: CP-1190D
(ii) Title of Paper: Field Theory
(iii) UNITS **No. of Lectures:**

Unit I: Field Extensions
Extension of a field, Algebraic extensions, Algebraically closed fields, Derivatives and multiple roots, Finite Fields. **15 Lectures**

Unit II: Galois Theory
Separable and normal extensions, Automorphism groups and fixed fields, Fundamental theorem of Galois theory. **15 Lectures**

Unit III: Finite Fields
Prime fields, Fundamental theorem of algebra, Cyclic extensions, Cyclotomic extensions.
15 Lectures

Unit IV: Applications of Galois theory
Constructions by ruler and compass ,Solvable groups ,Polynomials solvable by radicals.
15 Lectures

Unit V: Examples, Seminars and group discussion on the above four units. **15 Lectures**

Recommended Books:

1. U. M. Swamy, A. V. S. N. Murthy, Algebra: Abstract and Modern, Pearson Education, 2012.
2. M. Artin, Algebra, PHI, 1996 .

Reference Books:

1. Basic Algebra I, second edition, Nathan Jacobson, W. H. Freeman and company, New York .
2. I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd.
3. Bhattacharya, Jain and Nagpal,Basic Abstract Algebra, 2nd edition, Narosa Publishing House, New Delhi.
4. A first course in Abstract Algebra by John Fraleigh (3rd edition) Narosa publishing house, New Delhi
5. I. T. Adamson, Introduction to Field Theory, second edition, Cambridge University Press,1982.

(i) Paper: CP-1191D

(ii) Title of Paper: Integral Equations

(iii) UNITS **No. of Lectures:**

UNIT– I Classification of linear integral equations, Conversion of initial value problem to Volterra integral equation, Conversion of boundary value problem to Fredholm integral equation, Separable kernel, Fredholm integral equation with separable kernel, Fredholm alternative. Homogeneous Fredholm equations and eigen functions. **15 Lectures**

UNIT –II Solutions of Fredholm integral equations by: Successive approximations Method, Successive substitution Method, Adomian decomposition method, Modified decomposition method, Resolvent kernel of Fredholm equations and its properties, Solutions of Volterra integral equations: Successive approximations method, Neumann series, Successive substitution Method.

15 Lectures

UNIT –III Solution of Volterra integral equations by Adomian decomposition method, and the modified decomposition method, Resolvent kernel of Volterra equations and its properties, Convolution type kernels, Applications of Laplace and Fourier transforms to solutions of Volterra integral equations, Symmetric Kernels**:** Fundamental properties of eigenvalues and eigenfunctions for symmetric kernels, expansion in eigenfunctions and bilinear form.

15 Lectures

UNIT – IV Hilbert Schmidt Theorem and its consequences, Solution of symmetric integral equations, Operator method in the theory of integral equations, Solution of Volterra and Fredholm integrodifferential equations by Adomian decomposition method, Green's function: Definition, Construction of Green's function and its use in solving boundary value problems.

15 Lectures

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book(s):

1. R. P. Kanwal, Linear Integral Equation- Theory and Technique, Academic Press, 1971.
2. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations-Methods and Applications, Springer, 2011

Reference Books:

1. L. G. Chambers, Integral Equations- A Short Course, International Text Book Company, 1976.
2. M. A, Krasnov, et.al. Problems and exercises in Integral equations, Mir Publishers, 1971.
3. J. A. Cochran, The Analysis of Linear Integral Equations, Mc Graw Hill Publications, 1972.
4. C. D. Green, Integral Equation Methods, Thomas Nelson and sons, 1969.

(i) Paper: CP-1192
(ii) Title of Paper: Algebraic Number Theory
(iii) UNITS **No. of Lectures:**

Unit I
Revision of rings, polynomial rings and fields, Field extensions, Symmetric polynomials, Modules, Free Abelian groups. **15 Lectures**

Unit II
Algebraic Numbers, Algebraic number fields, Conjugates and Discriminants, Algebraic integers, Integral Bases, Norms and Traces, Ring of integers, Quadratic fields, Cyclotomic fields.
15 Lectures

Unit III
Factorization into irreducibles, Noetherian rings, Dedekind rings, Examples of Non- Unique factorization into irreducibles, Prime factorization, Euclidean Domains, Euclidean quadratic fields.
15 Lectures

Unit IV
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 Lectures**

Unit V Examples, Seminars and group discussion on the above four units. **15 Lectures**

Recommended Books:
1.Algebraic Number Theory by I.N. Stewart & D.O. Tall, Academic press.

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

Paper: CP-1193D
Title of paper: Graph theory – II

(iii) UNITS **No. of Lectures:**

Unit 1 : Preliminaries, Incidence Matrix : Rank, Minors, Path Matrix, Integer generalized inverse, Moore –Perose inverse, 0-1 incidence matrix, matchings in bipartile graphs.

15 Lectures

Unit 2 : Adjacency Matrix, Eigenvalues of some graphs, Determinant, Bounds, Energy of graphs, Antiadjacency matrix of directed graph, nonsingular trees .

15 Lectures

Unit 3 : Laplacian matrix : Basic properties, Computing Laplacian egien values, Marrix tree theorem, Bounds for Laplacian special radius, Edge – Laplacian of a tree, Cycles and cuts, Fundamental cycles and fundamental cut, Fundamental matrices, Minors.

15 Lectures

Unit 4 : Regular graphs : Person – Frobinius Theory, Adjacency algebra of regular graphs, Strongly regular graph and Friendship theorem, Graphs with maximum energy, Algebraic connectivity, classification of trees, spanning tress and binary trees. Kruskal's Algorithm for shortest spanning trees.

15 Lectures

Unit 5 : Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended books :

1. R.B. Bapat : Graphs and matrices, Hindustan book agency.

Reference books :

1. Douglas B. West : Introduction to Graph Theory Person Education Asia.
2. F. Harary – Graph Theory, Narosa publishing house (1989).
3. K.R.Parthsarthy : Basic Graph Theory, Tata McGraw Hill publishing Co.Ltd. New delhi.
4. Discrete Mathematics by S.R Patil, M.D Bhagat, D.M. Pandhare.

Paper: CP-1194
Title of Paper: Operations Research –II
(iii) UNITS **No. of Lectures:**

Unit I: Replacement Problems, Failure mechanism of items, Replacement policy for items whose maintenance cost increases with time and money values is constant, Group replacement ofitems that fail completely. **15 Lectures**

Unit II: 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 Lectures**

Unit III: 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 Lectures**

Unit IV: Information Theory : Communication process, Quantitative measure of information, Abinary unit of information, measure of uncertainty of entropy, basic properties of entropyfunction (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 Network diagram, determination of the critical path. **15 Lectures**

Unit V: Examples, Seminars and group discussion on the above four units. **15 Lectures**

Recommended Books:

1. S.D.Sharma : Operations Research Kedarnath and co. 1999.

Reference Books:

1. KantiSwarup ,P.K.Gupta and Manmohan : Operations research, S.Chand& Co.
2. HamadyTaha : Operations Research :Mac Millan Co.
3. S.D.Sharma :Linear programming, Kedarnath,Romnath& Co.
4. S.D.Sharma : Nonlinear and Dynamic programming KedarNath Ram Nath and Co. Meerut
5. R.K.Gupta : Operations Research Krishna PrakashanMandir, Meeru
6. G.Hadley : Linear programming, Oxford and IBH Publishing C

Paper: CP1195D
Title of Paper: Fluid Dynamics
(iii) UNITS **No. of Lectures:**

Unit I: Physical properties of fluids and kinematics of fluids: Concepts of fluids, continuum hypothesis, density, specific weight, specific volume, pressure, viscosity, surface tension,Eulerion & Lagrangian methods of description of fluids, Equivalence Eulerian and Lagrangian method, General motion of a fluid element, Integrability and compatibility conditions, stream lines, path lines, streak lines, stream function, vortex lines, circulation. **15 Lectures**

Unit II. Stresses in fluids: Strain rate tensor, stress tensor, normal stress, shearing stress, symmetry of stress tensor, Transformation of stress components from one co-ordinate system toanother, principle axes and principle values of stress tensor. Newtonian fluids, non Newtonian fluids, purely viscous fluids, Constitutive equations. **15 Lectures**

Unit III. Conservation laws: Equation of conservation of mass, equation of conservation of momentum, Navier-Stokes equation, equation of moment of momentum, Equation of energy,Basic equations in different co-ordinate systems: Cartesian co-ordinate system, Cylindrical coordinate system, Spherical co-ordinate system, general orthogonal curvilinear co-ordinate system, boundary conditions. **15 Lectures**

Unit IV. Rotational and irrotational flows, Dynamic Similarity: Theorems about rotational and irrotational flows: Kelvins minimum energy theorem, Gauss theorem, Kinetic energy of aninfinite fluid, uniqueness of irrotational flows Bernoullis's equation, Bernoullis equation for irrotational flows, Two dimensional irrotational incompressible flows, Blasius theorem, circle theorem, Sources and sinks, sources, sinks and doublets in two dimensional flows, Methods of images. Dimensional analysis, Non dimensional numbers, some applications of non-dimensional analysis. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books:

1. An introduction to Fluid Dynamics' R. K. Rathy, Oxford & IBH publishing company
2. Text book of Fluid Dynamics' F. Chorton CHS Publishers, Delhi, 1985

Reference Books:

1. Fluid Mechanics' L. D. Landay & E. M. Lipschitz Pergamon Press London 1985
2. Fluid Mechanics' Kundu & Cohen, Elsevier pub 2004

(i) Paper: CP-1196D
(ii) Title of Paper: Dynamical Systems-II
(iii) UNITS **No. of Lectures:**

Unit I
Basic concepts of nonlinear dynamics: **15 Lectures**
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.
Unit II
Stability analysis: **15 Lectures**
The flow defined by a differential equation, Linearization, Stable manifold theorem, Hartman-Grobman theorm, Stability and Lyapunov functions, Bifurcation.
Unit II
Chaos: **15 Lectures**
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.
Unit IV
Applications and computer experiments: **15 Lectures**
Application of chaos to secure communication, Introduction to fractals, Use of computer softwares 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.

Unit VI Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book(s):
1. Differential Equations and Dynamical Systems, Perko, Springer, New York.
2. Chaos - an introduction to dynamical systems, Alligood, Sauer and Yorke, Springer, New York.
Reference Books:
1. Differential equations, dynamical systems, and an introduction to chaos, M. Hirsch, S. Smale and R. L. Devaney, Elsevier Academic Press, USA, 2004.
2. Nonlinear dynamics and chaos, Strogatz, Perseus Books, New York.
3. Introduction to applied nonlinear dynamics and chaos, Wiggins, Springer, New York. (Algorithms)
4. Dynamical systems: differential equations, maps and chaotic behavior, Arrowsmith and Place, Chapman and Hall, London. (Applications)
5. Differential dynamical systems, Meiss, SIAM, Philadelphia.

(i) Paper: CP-1197D
(ii) Title of Paper: Combinatorics
(iii) UNITS **No. of Lectures:**

Unit I : The sum Rule and the product Rule ,Permutations and combinations ,The Pigeonhole Principle ,Ramsey Numbers ,Catalan Numbers ,Stirling Numbers. **15 Lectures**

Unit II: Generalized Permutations and combinations, Multinomial Theorem ,The Inclusion – Exclusion principle, Sieve's formula ,Derangements ,System of Distinct Representatives (SDR), Combinatorial Number theory. **15 Lectures**

Unit III : Rook- Polynomial ,Ordinary and Exponential generating functions ,Partitions of a positive integer ,Recurrence Relations, Fibonacci sequence. **15 Lectures**

Unit IV : Group Theory in Combinatories ,The Burnside Frobenius Theorem,Permutation Groups and Their Cycle Indices , Polya's Enumeration Theorems. **15 Lectures**
Unit V: Examples, Seminars and group discussion on the above four units. **15 Lectures**
Recommended Book(s):

1. V.K. Balakrishnan Schum's Outline of Theory and problems of combinatorics. Schum's Outline Series Mc. Grew Hill INC

2. Richard A Broadly, Introductory combinatorics New Holland.

Reference Books:

1. Alan Tucker – Applied Combinatorics. – John Willey Sons.

2. Sharad Sane- Combinatorial Techniques-Hindustan Book Agency

(i) Paper: CP-1198D
(ii) Title of Paper: Fractional Differential Equations
(iii) UNITS **No. of Lectures:**

Unit I: 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 $(t-a)^{\beta}$, 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, RL fractional derivative of $(t-a)^{\beta}$. **15 Lectures**

Unit II: 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 **15 Lectures**

Unit III: Laplace transforms of fractional derivatives- Laplace transform of the Riemann-Liouville fractional derivative, Caputo derivative and Grünwald-Letnikov fractional derivative. Fourier transforms of fractional integrals and derivatives. Mellin transforms of fractional derivatives-Mellin transforms of the Riemann-Liouville fractional integrals and fractional derivative, Mellin transforms of Caputo derivative. **15 Lectures**

Unit IV: 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 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended
Book(s):

1. Igor Podlubny, Fractional differential equations. San Diego: Academic Press; 1999.

Reference
Books:

1. A. Kilbas, H.M. Srivastava, J.J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006.
2. Kai Diethelm, The Analysis of Fractional Differential Equations, Springer, 2010.
3. L. Debnath, D. Bhatta, Integral Transforms and Their Applications, CRC Press, 2010.
4. Shantanu Das, Functional Fractional Calculus, Springer, 2011.