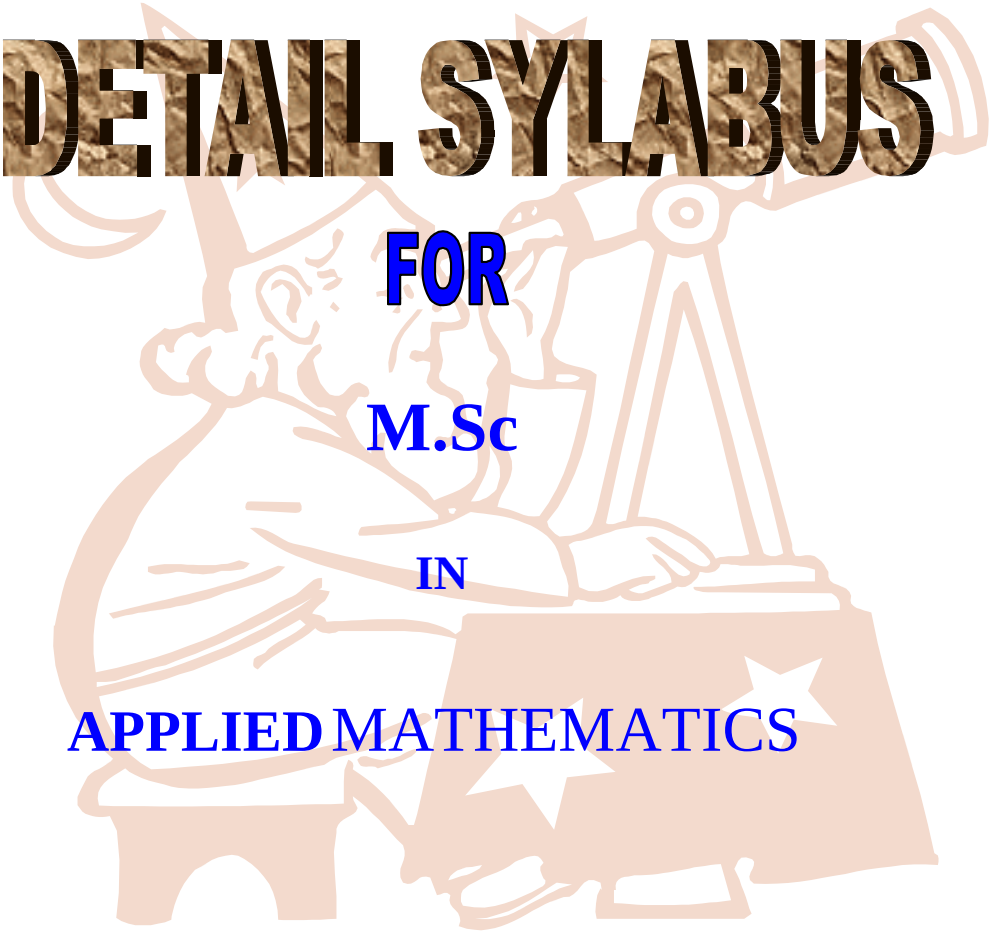
# DETAIL SYLABUS

## FOR

## M.Sc

**IN**

## APPLIED MATHEMATICS



**DEPARTMENT OF MATHEMATICS**

VSSUT- BURLA

**2011-2013**

**ODISHA, 768018**

**DEPARTMENT OF MATHEMATICS,**
**V. S. S. University of Technology, BURLA Odisha, 768018**
**SEMESTER WISE SYLLABUS FOR MSc PROGRAM**
**EFFECTIVE FOR THE SESSION 2011-13**
**UNDER ACADEMIC AUTONOMY**

| | **Semester – I** | |
|---|---|---|
| BSM-511 | Real Analysis | 4Credits |
| 512 | Complex Analysis | 4Credits |
| 513 | Modern Algebra | 4Credits |
| 514 | Probability | 4Credits |
| 515 | Programming in -C- | 4Credits |
| 516 | Programming Lab & Viva | 4Credits |
| | TOTAL | 24 credits |
| | **Semester – II** | |
| 521 | Measure Theory and Integration | 4 Credits |
| 522 | Ordinary Differential Equations | 4Credits |
| 523 | Statistical Methods | 4Credits |
| 524 | Mathematical Modelling | 4Credits |
| 525 | Numerical Analysis | 4Credits |
| 526 | Practical & Viva | 4Credits |
| | TOTAL | 24 credits |

| | | |
|---|---|---|
| | **Semester –III** | |
| 531 | Linear Programming | 4Credits |
| 532 | Discrete Mathematical Structures | 4Credits |
| 533 | Functional Analysis | 4Credits |
| 534 | Partial Differential Equations | 4 Credits |
| 535 | Linear algebra | 4 Credits |
| 536 | Project stage-I & viva | 4+4=8 credits |
| | TOTAL | 28 credits |
| | **Semester –IV** | |
| 541 | General Topology | 4 Credits |
| 542 | Mathematical Methods | 4 Credits |
| 54E* | Three Electives from schedule –A 12Credits(4x3) | 12 Credits |
| 544 | Project stage-II & viva voce | 4+4= Credits |
| | TOTAL | 28 credits |
| | GRAND TOTAL | 104 credits |

## Semester –I

# REAL ANALYSIS

### Unit-I

Sets, Relation, Function, Axioms for Real numbers, Axioms of Choice and equivalents (without proof), Cardinality, Countability, elements of set theory for metric space and in particular for $R^n$ including Bolzano-Weiestrass and Heine-Borel theorems, sequences and series of real numbers, convergence, Tests of Convergence, Cauchy criterion for convergence.

### Unit-II

Real valued function, Properties of real valued continuous function on $R^n$, Uniform continuity, Sequences and series of functions, Uniform convergence. Power series, Weiestrass approximation theorem.

### Unit-III

Differentiation, Reimann-Stieltjes integral of real valued function w.r.t a monotone function & its properties, Linearity, Integration by parts and change of variables, Term by term integration, Differentiation & integration under the integral sign.

### Unit-IV

Function of several variables, Differentiability, Inverse function theorem, Implicit function theorem, constrained maxima and minima.

*Books Recommended: -*


1. Rudin Walter (1976): Principle of Mathematical Analysis, McGraw Hill, Third edition
2. Apostol T.M. (1985): Mathematical Analysis, Narosa Publishing House, and Indian edition.
3. Hewitt and Stromberg: Real and Abstract Analysis.
4. G. Das and S. Pattanayak: Fundamentals of Analysis, TATA Mc Graw Hill.


# COMPLEX ANALYSIS

### Unit – I

The complex Number system, The spherical representation , Analytic functions , Power Series, Exponential and trigonometric functions.

### Unit – II

Conformal mapping, Mobious transformation, Cross-ratio.

### Unit –III

Riemann- stieltjes integral, Power Series representation of Analytic functions, The index of a closed curve, Cauchy's theorem for rectangle, Cauchy theorem for disc, Cauchy's integral formula, Liouville's theorem, Fundamental theorem of Algebra, Morera's theorem, Open mapping theorem.

### Unit – IV

Zeros, Poles, Classification of Singularities, Laurent Series, Residues, The Argument Principle, Rouche's theorem, The Maximum Modulus theorem, Schwarz's Lemma.

*Books for reference*


1. J. B. Conway — Functions of one Complex Variable, Norosa.
2. Lars, V. Ahlfors — Complex Analysis, Mc Graw Hill.
3. E. Titchmarsh — Theory of Functions, OXFORD.


# MODERN ALGEBRA

**Unit – I**

Review of Group theory: Groups, Subgroups, Normal Subgroups, Quotient groups, homomorphism, Isomorphism, Cyclic groups, Permutation groups, Symmetric groups, Caylay's Theorem.

**Unit – II**

Direct products, Series of groups, Groups Action on a set, Sylow theorem, Application of Sylow Theorem, Free Abelian groups, Free Groups.

**Unit – III**

Vector Spaces, Subspaces, Quotient spaces, Linear independence, bases, Dimension, Projection, Algebra of matrices, Rank of a matrix, Characteristic roots and Vectors.

**Unit – IV**

The Algebra of Linear transformation, Kernel, range, matrix representation of a linear transformation, Change of bases, Linear functionals, Dual space, eigen values, eigen vectors, Cayley-Hamilltorn theorem, Canonical Forms: Diagonal forms, triangular forms, Jordan form, Quadratic form, Inner Product spaces.

*Books for reference*


1. I. N. Herstein — Topics in Algebra, Vikas Publilcation.
2. J. B. Fraleigh — A first course in Algebra, Norosa.
3. A. Ramachandra Rao and P. Bhimsankaram. Linear Algebra, Tata Mc Graw Hill.
4. P.P. Halmos — Finite Dimensional Vector Spaces,
5. Mirsky — Linear Algebra
6. Hoffman & Kunze — Linear Algebra.
7. S. Kumaresan — Linear Algebra.

# PROBABILITY

## Unit-I

Sigma-algebra, Measurable spaces and product spaces, measurable transformations, additive set function, Measures and probability spaces, Induced measures and distribution functions and its decomposition.

## Unit-II

Poisson theorem, Interchangeable events and their limiting properties, Bernoulli and Borel theorems, Central limit theorem for binomial random variables.

## Unit-III

Independence of sequence of events and random variables, Multiplication properties, random allocation of balls into cells Borel Cantelli theorem and characterization of independence.

Tail-sigma field, 0-1 Law of Borel and Kolmogorov, limits of random variables.

## Unit-IV

Convergence of random variables, Convergence in probability, almost surely, in the mean and in distribution,Their relationships.

*Books for Recommended:-*


1. H.G. Tucker(1967) : A graduate course in probability (A.P)
2. Y.S. Chow and H. Teicher(1979) : Probability theory, Springer-Verlag.


## PROGRAMMING LANGUAGE –C-

Unit I :

Overview of C: Introduction, importance of C, sample C programs, Basic structure,
Programming style, executing a C-programme.
Constants, Variables and data types: Introduction, character set, C-tokens, key words and
identifiers, constants, variables, data types, declaration of variables, assigning values to
variables, defining symbolic constants.
Operators and Expressions: Introduction, Arithmetic, Relational, Logical, Assignment,
Increment and Decrement and Special operators, arithmetic expressions, evaluations of
expressions, precedence of arithmetic operators, type conversions in expressions,
operator precedence and mathematical functions.
Managing input and output operators: Introduction, reading a character, writing a

character, formatted input and formatted output.
Unit II :
Decision making and branding: Introduction, Decision making with IF statement, simple
IF statement, the IF-ELSE statement, nesting of IF-ELSE statement, the ELSE-IF ladder,
the SWITCH statement, the ? operator, GOTO statement.
Decision making and Looping: Introduction, the WHILE statement, the DO statement,
FOR statements, jumps in loops.
Unit III :
Arrays: Introduction, One dimensional arrays, two dimensional arrays, initializing Two
dimensional arrays, Multi dimensional arrays.
User defined functions: Introduction, need for user defined functions, a multi function
program, the form of C-functions, Return values and their types, calling a function,
category of functions, no arguments and no return values, arguments but no return values,
arguments with return values, handling of non-integer functions, nesting of functions,
Recursion, Function with arrays, the scope and life time of variables in functions, ANSI
C functions.
Unit IV :
Structures and Unions: Introduction, Structure definition, giving values to members,
Structure initialization, comparison of structures, variables, arrays of structures,
structures within structures, structures and functions, Unions, size of structures, Bit fields.
Pointers: Introduction, understanding pointers, accessing the address of variables,
declaring and initializing pointers, accessing through its pointers, pointer expression,
pointer increments and scale factor, pointers and arrays, pointer and character strings,
pointer and function, pointer and structures, pointers on pointers.
13
Unit V :
Dynamic memory allocation and Linked lists: Introduction, Dynamic memory allocation,
concepts of linked lists, advantage of linked lists, types of linked lists, pointers revisited,
basic test operators, application of linked lists.
The Preprocessors: Introduction, Macro substitution, file inclusion, compiler control
directives, ANSI addition.
Text Book:

1. E. Balagurusamy, “Programming in ANSI C’, Tata MCGraw Hill, Publishing Company Ltd., (2nd edition), New Delhi.
2. Chapters 1 to 7, 9, 11 and 14.
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# PROGRAMMING LABORATORY

**The candidates should be able to handle with DOS, MsOffice, and Windows and do the following programmes by a computer in C**

1. Application of Euclidian Algorithm to find gcd of two numbers.
2. Generation of Fibonacci sequence using recursion and find the number that are perfect square.
3. Generate a list of primes between 1 and n. Find the twin primes & count no of primes of the form 4n+1 & 4n-3.
4. Test the truth of Bertrand conjecture (Bertrand conjecture is that there is at least one prime between n and 2n)
5. Write a program to find all factors of a number.
6. Construct a magic square dimension n x n (n is odd)
7. Draw Pascal’s triangle.
8. Write a program to test $\varphi(mn)=\varphi(m)\varphi(n)$.
9. Investigate the average value of $\varphi(n)$ computing $\sum_{d/n}\varphi(d)$
10. Write a program to multiply two numbers having more than 15 digits each.
11. Determination of Roots by:
    a) Bisection Method.
    b) Regula – Falasi Method.
    c) Newton Raphson Method.
12. Interpolations
    a) Lagrange Interpolation.
    b) Newtonian Interpolation.
13. Numerical Integration
    a) Trapezoidal Rule.
    b) Simpson’s 1/3 Rule.
    c) Simpson’s 3/8 Rule.
14. Numerical solution of Differential Equation
    a) Ranga Kutta Method.
    b) Euler Method.
15. Matrix Inversion
    a) Gauss Elimination Method.
    b) Gauss Seidal Method.
16. Evaluation of limits.
    a) $\lim_{x\to\infty}(1+1/x)$ b) $\lim_{x\to\infty} n(a^{1/n}-1)$ c) $\lim_{x\to 0}(1+x)^{1/x}$
    d) $\lim_{x\to 0}(e^x-1)/x$ e) $\lim_{x\to 0}\{(1+x)^n-1\}/x$

17. Summation of series
    a) $\sum 1/n! = e$  b) Sine series  c) Cosine series
18. Generation of Logarithmic Table
19. Curve tracing.
    Circle, Ellipse, Parabola, Hyperbola, Sine Curve, Cosine Curve, Cissoid, Cardioids ( $r = a(1+\cos(\theta))$, Limacon ($r = a + b\cos(\theta)$), Archimedean Spiral ($r= a$), Equiangular Spiral ( $r = A e^{m}$) , Lemniscates ($(a(x^2+y^2)=(x^2+y^2)^2$ ) , Folium of Descartes ( $x^3+y^3 – 3axy = 0$), Astroid ($x^{2/3}+y^{2/3} = a^{2/3}$)
20. Find Fourier coefficient of different functions and draw the Fourier graphs.

21. Data Handling.
    Sorting : Bubble sort, Quick sort, Merge sort.
    Searching : Linear search, Binary search
23. Generation of random number.
24. Determination of rank of any n x m matrices.

**Semester – II**

# MEASURE THEORY AND INTEGRATION

## Unit-I

Sigma Algebra of Sets, Borel sets of **R**, Lebesgue outer measure and its properties, Sigma Algebra of Measurable sets in **R** , Non-measurable sets, Measurable sets which is not a Borel set, Lebesgue measure and its properties, Cantor set and its properties,Measurable functions Simple function, Integration of Nonnegative functions, Riemann and Lebesgue Integration ,.

## Unit-II

Abstract measure spaces, Extension uniqueness and completion of a measure,Integration with respect to a measure, properties,Monotone convergence theorem, Fatou's Lemma, and Dominated convergence theorem,

## Unit-III

Modes of convergence,Point wise convergence and convergence in Measure, convergence diagrams and counter examples,Egorov's theorem,Differentiation of monotone functions, Lebesgue Differentiation theorem, Absolute continuity.

## Unit-IV

Complex and signed measure, Hahn decompositions, Jordan decomposition, Radon-Nikodym theorem ,Product measure, Fubini Theorem.

*Books Reference:-*

| | |
|---|---|
| 1. Measure Theory and Integration | Debarra. G. ( New age International) |
| 2. Real Analysis | Royden. H.L.(Pentice Hall of India) |
| 3. Real and Complex Analysis | Rudin W.(Tata McGraw Hill of India) |
| 4. Real & Abstract Analysis | Hewitt& Stromberg (Springer) |
| 5. Measure Theory & Integration | Rana. I.K. (New Age Publication) |

# ORDINARY DIFFERNTIAL EQUATIONS

A) Quick Review of linear differential Equations of Higher Order, Wronskian.

## Unit- I

**System of Linear Differential Equations: -** System of first order equations, Existence and Uniqueness theorems, Fundamental Matrix, Homogeneous and Non Homogeneous linear systems with constant Co-efficient, Linear system with periodic Co-efficient.

## Unit- II

**Existence and Uniqueness of Solutions: -** Successive approximation Picard's Theorem, Non Uniqueness of solutions, Continuation and dependence on Initial conditions, Existence of solutions in the large, Existence and uniqueness of solution of systems.

## Unit- III

**Oscillations of second Order Equations :-** Fundamental Results, Sturm's Comparison theorem of Hille wiener Oscillations of $x'' + a(t)x = 0$.

## Unit- IV

**Boundary Value Problems :-** Introduction ; Strum Liouville's Problem green's functions, Picard's throrem.

The course is covered by Chapter 2 (Quick Review ) 4,5,6,7 of "**Ordinary Differential Equations and stability theory**" by S. G. Deo and V. Raghavendra TATA Mc Graw Hill Ltd.

*Books for Reference: -*

| | | |
|---|---|---|
| 1. | G. Birkhoff & G. C. Rota | Ordinary Differential Equations<br>John Wiley & Sons, N.Y. |
| 2. | Coddington & Levinson | Ordinary Differential Equations |
| 3. | Tyn-Myint-U | Ordinary Differential Equations |
| 4. | L. Elsgolts | Differential Equations & calculus<br>of Variation Mir Publication. |

# STATISTICAL METHOD

## Unit-I

Random variable, Expectations, Moment Generating functions, Characteristic functions, Its properties, Statement of inversion theorem, Derivation of Characteristic function for a given distribution function and characteristic function for a given distribution function.

## Unit-II

Basic discrete distributions and their properties. Bernoulli, Binomial, Poisson, Negative Binomial, Geometric, Hypergeometric and uniform distributions, Their Characteristic function and moment generating functions, Sampling distribution of sum of observations for discrete distributions.

## Unit-III

Continuous distributions: Rectangular, Gamma, Beta, Normal, Cauchy, Exponential Lognormal distributions and their properties.

## Unit-IV

Sampling distributions:- Chi-square distribution, t-distribution, F-distributions and their properties, Inter-relationship between three distributions, Basic concept of testing of hypothesis:- Type I and Type-II errors. Power function and power curve. Neyman-Pearson's lemma for simple hypothesis against simple alternate hypothesis, Application of lemma for testing statistical hypothesis, uses of t-statistics, F-statistics and Chi-square statistics.

*Books Recommended:-*


1. An introduction to probability theory and Mathematical Statistics
   V.K. Rohatgi. Wiley Eastern.
2. Fundamental of Mathematical Statistics:
   S.C. Gupta and V.K. Kapoor.


# MATHEMATICAL MODELLING

## Unit- I

Need , Techniques , Classification and Characteristics of Mathematical Modelling , Mathematical Modelling Through $1^{st}$ order ODE , Linear growth and Decay Model, Compartment model, Modelling of Geometrical Problems.

## Unit- II

Mathematical Modelling Through system of First order ODE : Modelling on Population Dynamics, Epidemics compartment Models, Modelling in Economics, Medicine, Arms race, Battles and in duration al trades.

## Unit- III

Mathematical Modelling through Second Order O. D.E. : Modelling of Planetary motion, circular motion, Motion of satellite.

*Books for Reference : -*


1.J. N. Kapur Mathematical Modelling , Welley Eastern Ltd. 1990

2.D. N. Burghes Modelling through Differential Equations Ellis Horwood & John Wiley.

3.C. Dyson & e. Levery Principle of Mathematical Modelling Academic Press New York.

4. F. R. Giord ano & M.D. Weir. First Course in Mathematical Modelling Books Cole California.


# NUMERICAL ANALYSIS

## Unit-I

Number System and Errors: Introduction, Binary Number, Octal Numbers, Hexadecimal number, Floating point representation, Approximation of numbers, Error and Error propagation.

Root finding for non-linear equations: Bisection method, Iteration methods based on first degree equations( Secant method, Regula-Falsi method, Newton Raphson method), Iteration methods based on second degree equation(Muller method, Chebysev method), Rate of convergence , Iteration methods.

## Unit-II

Interpolations: Existence and uniqueness of interpolating polynomial, Lagrange and Newton interpolations, Error in interpolation, Finite differences, Interpolating polynomials using finite differences, Hermite interpolation, Piecewise and Spline interpolation.

## Unit-III

Differentiation: Methods based on Interpolation, Methods based on Finite Differentials, Methods based on undetermined coefficients, optimum choice of step length, Interpolation method.

Integration: Methods based on Interpolation( Trapezoidal rule , Simpson's rule), Method based on undetermined coefficiencts(Gausses Legendre Integration method, Lobatto integration method , Radon integration method, Gauss-chebysev Integration method(without derivation), Gauss-Laguerre Integration method (without derivation) , Gauss-Hermite Integration methods(without derivation), Composite integration methods, Error estimate.

## Unit-IV

Numerical Solution of system of linear equations: Direct methods, Gauss Elimination

methods, Gauss-Jordan Elimination method, Triangularization method, Cholesky method, Iteration methods(Jacobi iteration method, Gauss-siedel iteration method, Iterative method for $A^{-1}$ ) Eigen value problems(Jacobi method for symmetric matrices) Givens Method for symmetric matrices, Rutishauser method for arbitrary matrices).
Numerical solution of ordinary differential equation: Euler Method, Backward Euler method, Mid-point method, Single Step methods(Tayler series method, Range-kutta method(Second order, Fourth order method)

*Books for Reference:-*
1 M.K. Jain , S.R.K Iyengar, R.K. Jain: Numerical Methods for Scientific and Engineering Computation , Willey Eastern Ltd. New Delhi (1995)

Unit-I : Chapt-I 1.3 ; Chapt-II 2.1,2.2,2.3,2.4,2.5,2.6.;
Unit-II: Chapt-IV 4.1,4.2,4.3,4.4,4.5,4.6,4.8,4.9,4.10;
Unit-III: Chapt-V 5.1,5.2,5.3,5.4,5.6,5.7,5.8,5.9;
Unit-IV: Chapt-III- 3.1,3.2,3.4,3.5;Chapt-VI 6.1,6.2,6.3;

# PRACTICALS

**FOLLOWING ADVANCE PROGRAMM SHOULD BE DONE IN C**

**Matrix Algebra:**

1. Matrix addition using function or pointer
2. Matrix multiplication using function or pointer
3. Matrix Inverse
4. Solution of System of linear equation by following method
   a. Gauss Elimination Method
   b. Gauss Seidal iteration Method
   c. Gauss Jordan Elimination Method
5. Rank of a matrix
6. Determination of a Matrix
7. Solution of System of linear equation by Cremmers Rule
8. Eigen value and Eigen vector of a matrix

**Differential Equation:**

9. Solution of Initial value problem using following method and function
   a. Euler's Method
   b. Backward Euler Method
   c. Eulere-Richardson's Method
   d. Second order Ranga-Kutta Method
   e. Milne's predictor corrector Method
   f. Gauss predictor corrector Method
10. Solution of boundary value problem.
11. Solution of parabolic Partial Differential equation by following method
    a. Schmidt Method

b. Laasonen Method

**Graph of curve in C**

12. Following curve should be trace using “graphic.h” in C
(i.) Circle (ii.) Elipse (iii.) Hyperbola (iv.) Sine Curve (v.) Cosin curve (vi.) Cissoid (vii.) Cardioid ($r = a(1+\cos(\theta))$) (viii.) Limacon ( $r= a+b\cos(\theta)$) (xi) Laminscate ($a(x^2+y^2)=(x^2 + y^2)^2$)

**Linear Programming Problem:**

13. Solution of LPP by Simplex Method
14. Solution of LPP by Revise Simplex Method
15. Transportation Problem
16. Assignment Problem
17. Travel Salesman Problem.

**Semester – III**

# LINEAR PROGRAMMING

## Unit-I

Mathematical formulation of LPP, Simplex Method, Solution of Simultaneous linear equation using Simplex method ,

## Unit-II

Primal and Dual Problem, Duality & Simplex method, Dual Simplex Method, Post optimal Analysis-Changes in the Cost Vector, Changes in the resource vector and Changes in the coefficient matrix.

## Unit-III

Transportation Problem, Properties of transportation matrix, N-W corner rule, Vogel's approximation method, and Transportation algorithm, Assignment Problem.

## Unit-IV

Theory of Games, Two person zero sum games, Maxmin and Minmax principle, Graphical Solution of 2xn and nx2 games, General Solution of rectangular games by LP method.

*Book for reference: -*


1. S. K. Gupta — Linear Programming and network Models.
2. S. I. Gass — Linear Programming and its Applications.
3. G. Hardley — Linear Programming.
4. Kanti swarup — Operations Research.


# DISCRETE MATHEMATICAL STRUCTURES

## Unit-I

Review of relation functions, Permutation Combination and discrete Probability, Computability and formal language, Russell's Paradox and Noncomputability, Ordered sets, Languages, Phrase Structure grammars, Types of Grammars and Languages.

## Unit-II

Graphs: Basic terminology, Multi graph and Weighted graphs, Paths and circuits, Eulerian Paths and circuits, Hamiltonion Paths and circuits, Trees: Rooted trees, binary search trees, Spanning trees, Cut sets,

## Unit-III

Finite state machines: Finite state machines as models of physical system, Equivalent

machines, Finite state machine as languages recognizers, Recurrence relations and recursive Algorithms.

### Unit-IV

Boolean Algebras: Lattices and Algebraic systems, Principle of Duality, Basic Properties of Algebraic systems defined by Lattices, Distributive and complemented Lattices, Boolean lattices and Boolean algebras, Uniqueness of finite Boolean algebras, Boolean function and Boolean expressions. Prepositional Calculus.

*Books for Reference:-*

C.L Liu Elements of Discrete Mathematics (second edition) Tata McGraw Hill edition

# FUNCTIONAL ANALYSIS

### Unit – I

Review of Metric spaces, $L^p$ – spaces, Inequalities in $L^p$ – spaces, Completeness of $L^p$ . Normed linear spaces, inner product spaces examples, properties of Normed linear spaces and inner product spaces, Continuity of linear maps.

### Unit –II

Hilbert spaces, Examples, orthonormal sets, Gram-Schist orthonormalizations, orthonormal polynomials, Bessel's inequality, Riesz-Fisher Theorem, Orthonormal basis, Fourier Expansion, Parseval's formula, Projection theorem, Riesz Representation Theorem.

### Unit – III

Banach Spaces "Hahn Banach Theorem" Baire's category theorem ,Open mapping Theorem ,Closed graph theorem, Uniform boundedness Principle, duals and transpose dual of $L^p$ [a,b] and C [a,b] , Reflexivity.

### Unit – IV

Bounded Linear Operators on Banach Spaces, Banach algebra, definition, Examples, Spectrum of a bounded operator, Resolvant , Set, Compact operators on Banach spaces, spectrum of a Compact operator, Elementary ideas on integral equations, Unbounded Operators and fixed point theorems.

*Books for reference:-*

| | | | |
|---|---|---|---|
| 1. | Kreyszig | Functional Analysis | John Wiley |
| 2. | Limaye | Functional Analysis | Narosa |
| 3. | Goffman & Pedrick | A first Course in Functional Analysis | Wiley Eastern |
| 4. | Bachman & Narici | Functional Analysis. | |

# PARTIAL DIFFERENTIAL EQUATION

## Unit – I

: Meaning of Partial differential equation, Classification of first order Partial differential equations, Semi-linear and quasi-linear equations, Pfaffian differential equations, Lagrange's method, Compatible systems, Charpit's method, Jacobi's method,

**UnitII**

Integral surfaces passing through a given curve, Cauchy problem, method of characteristics for quasi-linear and non linear partial differential equation, Monge cone, characteristic strip. First order non-liner equations in two independent variables ,Complete integral.

## Unit – III

Linear Second order partial Differential Equations : Origin of second order p.d.e's, Classification of Second order Partial Differential Equations., One dimensional Wave equation, Vibration of an infinite string, origin of the equation, D'Alembert's solution, Vibrations of a semi finite string, Vibrations of a string of finite length, existence and uniqueness of solution, Riemann method,

**Unit – IV**

Laplace equation , Boundary value problems, Maximum and minimum principles, Uniqueness and continuity theorems, Dirichilet problem for a circle, Dirichlet problem for a circular annulus, Neumann problem for a circle, Theory of Green's function for Laplace equation, Heat equation, Heat conduction problem for an infinite rod, Heat conduction in a finite rod, existence and uniqueness of the solution, Classification in higher dimension, Kelvin's inversion theorem , Equipotential surfaces.

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*Books for Reference:-*


1. Phoolan Prasad and Renuka Ravindran — Partial Differential Equations, Wiley Eastern Ltd.
2. F. John — Partial Differential Equations, Springer-Verlag, New York.
3. Tyn-Myint-U — Partial Differential Equations North Holland Publication, New York
4 Amarnath — An elementary course in partial differential equation NAROSA

# Linear Algebra

Vector spaces over fields, subspaces, bases and dimension.

Systems of linear equations, matrices, rank, Gaussian elimination.

Linear transformations, representation of linear transformations by matrices, rank-nullity theorem, duality and transpose.

Determinants, Laplace expansions, cofactors, adjoint, Cramer's Rule.

Eigenvalues and eigenvectors, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonal-lization, rational canonical form, Jordan canonical form.

Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators, Rayleigh quotient, Min-Max Principle.

Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia, positive definiteness.

Texts / References

M. Artin, Algebra, Prentice Hall of India, 1994.

K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. Prentice-Hall of India, 1991.

S. Lang, Linear Algebra, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989.

P. Lax, Linear Algebra, John Wiley & Sons, New York,. Indian Ed. 1997

H.E. Rose, Linear Algebra, Birkhauser, 2002.

S. Lang, Algebra, 3rd Ed., Springer (India), 2004.

O. Zariski and P. Samuel, Commutative Algebra, Vol. I, Springer, 1975.

**Semester - IV**

# TOPOLOGY

## Unit – I

Basic concepts of Topology, Examples, Bases, Subbases, Countability, closed sets, Limit Points, Continuous functions.

## Unit – II

New topologies from old: - Subspace topology, Product topology, and Quotient topology.

## Unit – III

Connectedness, Local connectedness, Path-connectedness, compact Spaces, compactness in metric spaces, locally compacts spaces, $T_1$, $T_2$ – axioms, Regular and completely regular space, normal spaces, Urysohn Lemma,

## Unit – IV

Tychonoff Theorem, Homotopy equivalences, Fundamental Group of a space, fundamental Group of $S^1$.

*Books for reference:-*


1. J.R. Munkres — Topology – A First Course in Topology
2. Dugundji — Topology
3. Kelly — General Topology


# MATHEMATICAL METHODS

## Unit-I

INTEGRAL TRANSFORMS:-

Laplace transforms: Definitions, Properties, Laplace transforms of some elementary functions, Convolution Theorem, Inverse Laplace transformation, Applications.

Fourier transforms, Definitions, Properties, Fourier transforms of some elementary functions, Convolution, Fourier transforms as a limit of Fourier Series, Applications to PDE.

## Unit-II

INTEGRAL EQUATIONS:

Volterra Integral Equations: Basic concepts, Relationship between Linear differential equations and Volterra integral equations, Resolvent Kernel of Volterra Integral equations, Solution of Integral equations by Resolvent Kernel, The Method of successive approximations, Convolution type equations, Solutions of integral differential equations with the aid of Laplace transformations.

## Unit-III

Fredholm Integral equations: Fredholm equations of the second kind Fundamental, Iterated Kernel, Constructing the resolvent Kernel with the aid of iterated Kernels, Integral equations with degenerate Kernels, Characteristic numbers and eigen

functions, solution of homogeneous integral equations with degenerate Kernel- non homogeneous symmetric equations Fredholm alternative.

### Unit-IV

CALCULUS OF VARIATIONS:
Extremal of Functionals : The variation of a functional and its properties , Euler's equations, Field of extremals, Sufficient conditions for the Extremum of a Functional conditional Extremum Moving boundary problem, Discontinuous problems, one sided variations, Ritz method.

*Books Recommended:-*

1. Sneddon I., The use of Integral Transformations (Tata McGraw Hill)
2. Schaum's Series, Laplace Transforms.
3. Gelfand and Fomin, Calculus of Variations (Prentic Hall, Inc)
4. Krasnov, Problems and Exercises in Calculus of Variations( Mir Publ)
5. Ram P Kanwa, Linear Integral Equations (Academic Press)

# LIST OF ELECTIVES

(EACH ELECTIVE IS OF 4 CREDITS)

How ever if necessary the academic council can frame a new course and offer it and it will be ratified in the next academic council.

## ADVANCED COMPLEX-ANALYSIS

### Unit- I

Harmonic functions (Definition and basis properties), The mean-value Property, Poisson's formula, Functions with the mean-value Property, Harnack's Principle, Sub harmonic function.

### Unit- II

Weierstrass theorem, Partial fraction and factorization, The Riemann – Zeta function, The Gamma function, Entire functions (Jensen's formula, Hadamard's theorem).

### Unit- III

Normal families, The Riemann-mapping theorem,

### Unit- IV

Elliptic functions, Picard's theorem

*Books for reference:-*

1. Lars, V. Ahlfors : Complex Analysis , Mc Graw Hill.
2. Conway, J.B. : Functions of one Complex Variables, Narosa.

## ANALYTIC NUMBER THEORY

## Unit-I

Fundamental Theorem of arithmetic, Arithmetical functions and Dirichlet Multiplication

## Unit-II

Average of arithmetical function, Elementary theorem in distribution of primes numbers

## Unit-III

Congruences, quadratic residues and Reciprocity law.

## Unit-IV

Ramanujan Sum. Reimann zeta function

*Books for Reference: -*


1. Tom. M. Apostal — An Introduction to Analytic Number Theory. Chapter 1,2,3¸4,5,8,9,12 .
2. Chandra Shekharan K. — Introduction to Analytic Number Theory.
3. G.H. Hardy & E.W. Wright. — Theory of Numbers.
4. I. Niven & H.S. Zukerman — An Introduction to Theory of Numbers
5. Richard Guy — Unsolved Problems in Number Theory. Springer Verlag


# ALGEBRAIC NUMBER THEORY

## Unit-I

Algebraic Numbers, Class field Theory.

## Unit-II

Quadratic Fields, diaphantine equations.

## Unit-III

Density of Sequence of Integers, Warring Problem.

## Unit-IV

Fermat's Theorems, Representation of a numbers a sum of two & Four squares.

*Books for Reference: -*


1. G.H. Hardy and Wright — Theory of Numbers
2. I. Niven and H. S. Zukerman — An Introduction to Theory of Number
3. S. Lang — Algebraic Number Theory
4. P. Ribenboim — Algebraic Number Theory

# ALGEBRAIC TOPOLOGY

## Unit-I

Motivation and Historical background. Geometric complexes and Polyhedra, Orientation of simplex, simplicial Complexes and Simplicial maps. Review of Abelian Grourps, chains, Cycles, Boundary , Homology groups of simplicial complexes,examples of Homology groups, Structure of Homology groups, Relative Homology groups,Euler Poincare theorem.

## Unit-II

Homology Groups of $S^n$ , Homology of cone, relative Homology, Simplicial Approximation, Barycentric Subdivision, induced Homomorphism, Exact homolgy sequences, Mayer Vietories sequences, Eilenberg Steenrod Axioms.Singular Homology theory ,Axioms of singular theory,Excision in homology theory

## Unit-III

Cohomology,Simplicial cohomology groups,Relative cohomology,cohomology theory,Cohomology of free chain complexes,Cup products,CW complexes the cohomology of CW complexes,Join of two complexes, Homology manifolds, Poincare duality, cap products

Homotopic path , fundamental Groups, Covering Homotopy property for S' Examples of Fundamental groups, Relation between $H_1(K)$ and $\pi 1(|K|)$ , Definition of covering spaces classification of covering spaces, Basic Properties of Covering Spaces.

**Unit-IV**

*Books for Reference: -*


1. Munkres — Elements of Algebraic Topology Addition Wesley Publishing
2. Rotman — Algebraic Topology Springer Verlag.
3. Croom — Basic Concepts of Algebraic Topology. Springer
4. Spanier — Algebraic Topology Springer Verlag
5. Vick — Homology theory Academic Press.
6. Massy — Algebraic Topology.
7. Mounds — Algebraic Topology .


# COMBINATORICS

## Unit-I

Introduction and basis principles of permutations and combination.Pigeonhole Principle and inclusion and exclusive principle.

## Unit-II

Linear equations.

## Unit-III

Recurrence relations.

## Unit-IV

Generation functions.

Text Books

1. G. Berman Introduction to Combinatorics

*Books for Reference: -*

1. V. K. Krishnamurty Combinatorics
2. Conen Applied Combinatorics

# COSMOLOGY

## Unit-I

Field Equations, Exterior and Interior solutions, Crucial tests.

## Unit-II

Electromagnetism : Transformation formulae for density , electric charge, electric current, Electromagnetism in general Relativity, Propagation of electric and magnetic intensities. Transformation of differential operators. Tensor forms of Maxwell Equations.

## Unit-III

Static Cosmological Models, Geometrical and physical properties of the models, Comparison of models, Redshift Nonstatic Cosmological models, cosmological principles, derivation of Robertson walker line element, Friedman-Robertson-Walker cosmological models, Particle Horizons.

*Books for Reference: -*

1. R.C. Tolman Relativity, Themodynamics and Cosmology OXFORD
2. J. V. Narlikar Introduction to Cosmology, Cambridge Publication.
3. E. A. Lord Tensor, Relativity, Cosmology , TATA Mc Graw Hill.
4. S. Weinberg Gravitation and Cosmology, John Wiley New York.
5. M. R. Robonson Cosmology Oxford Univ. Press.
6. P. T. Landsberg & D. A. Evens Mathematical Cosmology (OXFORD)
7. M. Berry Principle of Cosmology Cambridge.
8. H. Bondi Cosmology, Cambridge Univ. Press.
9. Islam Mathematical Cosmology.
10. Weilnberg, S. Cosmology.

# DISCRETE DYNAMICAL SYSTEMS

## Unit-I

Phase Portraits, Periodic Points and Stable Sets, Sarkovskii's Theorem, Hyperbolic, Attracting and Repelling Periodic Points.
Families of Dynamical Systems, Bifurcation, Topological Conjugacy. The Logistic Function, Cantor Sets and Chaos, Period-Doubling Cascade

## Unit-II

More examples,Rotations, Horse shoes ,solenoid
Limit sets and recurrence,topological transitivity,topological mixing, expansiveness

## Unit-III

Topological entropoy, examples
. Symbolic Dynamics. Sub shifts and codes, subshifts of finite type,topological entropy of an SFT , Newton's Method.
Numerical Solutions of Differential Equations
.

## Unit-IV

Complex Dynamics, Quadratic Family, Julia Sets, Mandelbrot Set.
Topological Entropy, Attractors and Fractals, Theory of Chaotic Dynamical System.

*Books Reference:-*


1. Richard M. Holmgren: A First Course in Discrete Dynamical Systems,Springer Verlag(1996). For Unit-I to Unit-IV.
2. Devaney : Introduction to Chaotic Dynamical Systems.


# GALOIS THEORY

*Books for Reference: -*


1. M. P. Murty, Seshadri K. G.,Ramanatha and others TIFR
   Galois Theory Mathematical pamphlets Chp. 1, 2, 3, 4, 5.
2. E. Artin Galois Theory, Notre Dme Indiana.
3. N. Jocobson Lectures in Abstract Algebra vol 2.

# GRAVITATION

Pre requirements Differential Geometry and Riemannian Geometry

## Unit – I

Gravitational Field Equations Einstein field Equs from variational Principle.

## Unit – II

Classical Tests of Einstein Theory Schwarz child interior and exterior Solutions.

## Unit – III

Electromagnetism, Einstein Maxwillfield equations from action principle.

*Books for Reference: -*


1. B. A. Lord (Tata Mc Grow Hill) Tensor Relativity and Cosmology.
2. A Papa Petrou Lectures notes on General Relativity.
3. J. Foster(Riedel Pub.) Short Course in General Relativity.
4. R. C. Tolman Relativity, Thermo Dynamics and Cosmology.


# GEOMETRICAL METHODS IN PHYSICS

## Unit – I

**Differentiable manifolds and tensors :-** Definition and Example of manifolds, Sub Manifolds, Global considerations, Fibre Bundles, Lie Brackets and forms, Metric tensor, Tensor fields on manifolds , Frobenius Theorem.

## Unit – II

**Lie Derivative & Lie Groups :-** Lie dragging, killing Vector Lie Groups & theor Lie Algebras, Representation of rotation group.

## Unit – III

**Differential Forms :-** Algebra and integral calculus of forms, Geometrical Role of differential forms, Differential calculus of forms and its applications.

## Unit – IV

Application of Geometric method to Thermo dynamics and Cosmology.

*Books for Reference: -*


1. B. F. Schutz Geometrical Methods of Mathematical Physics. Cambridge University Press, 1980.

2. Ychoquet- Bruht, C. D. Moretle and M. D. Bleick
Analysis, Manifolds and Physics.
Northholoand, Amesterdam, 1977.
3. K. Yano Theory of Lie derivatives and its applications
North Holland, Amesterdam, 1955.
4. R. Hermann, Benjamin Vector bundles in Mathematical Physics.
Vols. I, II. 1970.
5. Varaeharajan Lie Groups & Lie Algebra, Springer
6. H. Flanders Differential Forms with Applications to the physical
Science , Academic Press N. Y. 1963.
7. M. Schreiber Differential Forms, Springer, 1977.

# LIE GROUPS AND LIE ALGEBRAS

## Unit- I

Differentiable manifolds , Analysis manifolds, Frobenius Theorem, Definition and example of Lie groups, Lie algebra, Lie algebra of a Lie group. Enveloping algebra of a Lie group. Subgroup , Sub algebras.

## Unit- II

Locally Isomorphic groups, homomorphism, Fundamental Theorem of Lie , Closed Lie subgroups and Homogeneous Spaces, Orbits and spaces of orbits , Exponential map. Taylor series expansion of a lie group . Adjoint representation, Differential of the Exponential map. Baker-Campbell Housdorff Formula.

## Unit- III

Lie theory of transformation groups representations Representations of abelian groups , representation of Lie algebras, Some analysis of Compact groups, The Theorem of Peter and Weyl and its applications. Structure theorem ( Elementary Ideas).

*Books for Reference : -*

1.Vardrajan, V.S. Lie Groups, Lie Algebra and their representation
Springer- Verlag.
2.Brocker, T. , Deeck, T. T. Representations of compect Lie grpups
Springer- Varlag.

# MECHANICS

## Unit- I

**Newtonian Mechanics** : Experimental facts, Investigation of Equation of Motion.

## Unit- II

**Lagrangian Mechanics** : Variational Principles, Lagrangian Mechanics on Manifolds,

## Unit- III

Oscillations, Rigid Bodies.

## Unit- IV

**Himiltonian Mechanics** : Differential forms, SimplCetic structure on manifolds

The course is covered by " Mathematical Methods in Classical Mechanics" by V.I. Arnold. Springer Verlag.

*Books for Reference : -*

1. Ordinary Differential Equations V. I. Arnold.

# OPERATOR THEORY

## Unit- I

Banach Algebra : Introduction , Complex homomorphism Basic properties of spectra, Commutative Banach Algebra : Ideals, Gelfand transform, Involution, Bounded operator .

## Unit-II

Bounded Operator : Invertibility of bounded operator, Adjoints, Spectru;m of bounded operatoer, Fundamentals of spectral Theory, Self adjoint operators, Normal, Unitary operators, Projection Operator.

## Unit- III

Resolution of the Identity, Spectral Theorem, Eigen Values of Normal Operators, Positive Operators, Square root of Positive operators, Partial Isometry, Invariant of Spaces, Compact and Fredholm Operators, Integral Operators.

## Unit- IV

Unbounded Operators : Introduction, Closed Operators, Graphs and Symmetric Operators, Cayley transform, Deficiency Indices, Resolution of Identity, Spectral Theorem of normal Operators, Semi group of Operators.

*Books for Reference : -*


| | |
|---|---|
| 1.Walter Rudin | Functional Analysis Tata McGraw Hill. |
| 2.Gohberg and Goldberg | Basic Operator Theory. |
| 3.M. Schecter | Principle of Functional Analysis |
| 4.Akhietzer and Glazeman | Theory of Linear Operator, Vol I, II Pitman Publishing House. |
| 5.Donford and Schwarz | Linear Operator, vol. 1. 2. 3. |
| 6.Weidman J | Linear Operators on Hilbort Speces, Speringer. |


# OPERATIONS RESEARCH

## Unit- I

Games and Strategies, Sequencing Problems

## Unit- II

Dynamic Programming.

## Unit- III

Integer Programming : -- Gomory's All - IPP Method and Bnach and Bound Algorithm. Network programming

## Unit- IV

Nonlinear Programming : -- Kuhn Tucker Conditions, Quadratic Programming , Wolfe's modified Simplex method, Beale's method.

*Books for Reference : -*


| | |
|---|---|
| 1.Kanti Swarup et al | Operation Research Sultan Chand & Sons. |
| 2.J. C. Pant | Introduction to Optimization and Operation Research. Jain Brothers, NEW DELHI. |


# QUANTUM MECHANICS IN HILBERT SPACE

## Unit- I

Physical and Electromagnetic bases of quantum mechanics probabilistic interpretation of quantum mechanics, schrodinger's equation, Linear Harmonic Oscillator and other one dimensional Problems, Hilbert space of systems of n-different particles in wave mechanics.

## Unit- II

Basic Operator theory, spectral measures spectral theorem for unitary operatrors.

### Unit- III

Basic postulates of Quantum Mechanics Function of compatible observable, Schrodinger, Heisenberg and Interaction pictures, State Vectors, Complete set of observable, Canonical Commutation relations,

### Unit- IV

Formalism of Wave mechanics, Completely continuous operators and the statistical operator, Basic concepts of scattering theory of two particles.

*Books for Reference : -*


1.Prugovecki, M. Quantum mechanics in Hilbert Spece.
2.Schecter, M. Operator Theory and Quantum Mechanics .
3.Schiff. L. I. Quantum Mechanics.
4.Mackey, J. Mathematical Foundation of Quantum Mechanics.


## RELATIVITY

### Unit- I

**Classical Theory** : - Space time, Newtonian Theory, Galilean Transformation of Velocity and Acceleration Electromagnetism and Galilean Transformation and Development of special theory of Relativity .

### Unit- II

**Special Theory Relativity** : - Special and General Lorentz Transformations, Consequences of Lorentz Transformations. Composition of Velocities, Proper Time, Transformation of Velocity and acceleration.

### Unit- III

**Relativistic Mechanics** : - Variation of mass with velocity, Equivalence of mass and energy and its applications , Relation between momentum and energy, mass, density, Force, Langragian and Hamiltonian.

### Unit- IV

**Minkowski-Spaces** : - Relativity and Causality, Null Cone, World Line of a Particles, Relativities Laws of Motion, Energy-momentum tensor.

### Unit- V

**General Theory of Relativity** : - Principles of Equivalence and Connivances, Field Equations, Schwarz-child Interior and Exterior solutions.

*Books for Reference : -*


1.Eric a. Lord — Tensors Relativity and Cosmology
TATA Mc Graw Hill Ltd., New Delhi

2.Synge J. L. (1956) — Relativity : The Special Theory
North Holland Publishing Company, Amsterdam.

3.Synge J. L . (1960) — Relativity : The General Theory
North Holland Publishing Company, Amsterdam

4.Alder, R., Bazin, M and Schiffer, M. (1975)
Introduction to General Relativiety, Mc Graw Hill.

5.Eddington, A. S. (1954) — The Methematical theory of Relativity
Cambridge University Press.

6.Resnick, R. (1968) — Introduction to Special Relativity
Cambridge University Press.

3. J. Foster (1979) — A short Course in General Relativity.

4. J. V. Narliker — General Relativity & Cosmology.
The Macmillan Company of India Ltd.

5. R. C. Tolman — Relativity Thermodynamics and Cosmology, OXFORD.


# SEVERAL COMPLEX VARIABLES

## Unit- I

Analytic functions of one complex variable, Elementary properties of functions of several complex Variables.

## Unit- II

Applications to commutative Banach Algebras, $L^2$ estimates and existence theorem for the Operator , Stein Manifolds, Local properties of analytic sheaves on stein manifolds.

*Books for Reference : -*


1.Lars Hormander — An Introduction to Complex Analysis in several variables.

2.Gunning is Rossi — Several Complex Variables, Springer Verlag.

3.Garner — Several Complex Variables, Springer Verlag.

4.Bochner & Martin — Functions of Several Complex Variables
University Press.


# STOCHASTIC PROCESS

## Unit-I

Fluctuation in coin tossing and random walk: The reflection principle, random walks, Basic concept of stochastic process, examples of stochastic process, classification of stochastic process according to state space and time domain, Gambler's ruin problem, Expected duration of game.

## Unit-II

Countable state Markov chains: Champman-Kolmogorov's equation, classification of n step transition probability and its limits, classification of states , period of Markov-chain.

## Unit-III

Stationary distributions of M.C. recurrence, Transient states, Probabilities. Birth and death process, Kolmogorov's differential equations, Poisson processes.

*Books for Recommended:-*


1. Samuel Karlin and H.M. Taylor — A first course in stochastic process
2. W. Fellor — An Introduction to probability theory and its applications(Vol. I)


# WAVELET

## Unit- I

Review of Fourier Analysis, Elementary ideas of signal processing, From Fourier Analysis to wavelet Analysis, Windowed Fourier Transforms : Time frequency localization, The reconstruction formulae.

## Unit- II

Multiresolution analysis, Construction of Wavelets from MRA construction of compactly supported wavelets, Band limited Wavelets, Franklin wavelets on real line, Introduction to spline analysis, spline wavelets on real line, Orthonormal Wavelets, Examples.

## Unit- III

Discrete transforms and algorithms, Discrete Fourier transform and the fast Fourier transform, Discrete cosine transform and the fast cosine transform, Decomposition and reconstruction algorithm for Wavelets, Wavelets and applications.

*Books for reference : -*


6. Harnandez, E. — A first Course in waveletes, CRC
7. Daubechies Ingrid — Ten Lectures on Wavetets.
8. Chui — An Intruduction to Wavetets, Academic Press.
9. Kaiser, G. — A friendly guide to Wavelets, Bikhauser 1994.
10. Kahane & Lemaire Rieusset — Fourier Series & Wavelets Gordon & Breach.

# GRAPH THEORY

## Unit- I

Definition and Examples, Connectedness, Walk, Path circuits, Euleriar graph, Hamiltonian graph, Some application.

## Unit- II

Trees : Elementary proportion of trees, Enumeration of trees, More application.
Cut sets:- Fundamental circuits and cut-sets, network flows, 1-isomorphism, 2-isomorphism.

## Unit- III

Planarity:- Kuratowski two graphs, detection of planarity, geometric dual, thickness and crossing.

## Unit- IV

Coloring problems, chromatic number, four color problem.

## Unit- V

Directed graph: Digraphs and binary relations, Euler digraphs.

*Text Books*

1. R. J. Wilson Introduction to Graph Theory

*Books for Reference: -*

1. N. Deo Graph Theory and its Application to Engineering and Computer Science.
2. F. Harary Graph Theory.

# ADVANCED FUNCTIONAL ANALYSIS

## Unit- I

Definition and Examples, Connectedness, Walk, Path circuits, Euleriar graph, Hamiltonian graph, Some application.

## Unit- II

Trees : Elementary proportion of trees, Enumeration of trees, More application. Cut sets:- Fundamental circuits and cut-sets, network flows, 1-isomorphism, 2-isomorphism.

## Unit- III

Planarity:- Kuratowski two graphs, detection of planarity, geometric dual, thickness and crossing.

## Unit- IV

Coloring problems, chromatic number, four color problem.

## Unit- V

Directed graph: Digraphs and binary relations, Euler digraphs.

*Text Books*

1. R. J. Wilson Introduction to Graph Theory

*Books for Reference: -*

1. N. Deo Graph Theory and its Application to Engineering and Computer Science.
2. F. Harary Graph Theory.