NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF MATHEMATICS

2-year **M. Sc. Program** in

'**Mathematics**' from the

Session 2015-2016

Name of the Course	: M. Sc. in Mathematics
No. of Intake	: 20 Nos. (As per rule)
Duration of Course	: 4 Semesters i.e. 02 years
Eligibility criteria	: Mathematics as Hons. /major subject from any recognized University.
Tuition Fees	: As per Institute rules
Curriculum	: Attached.

COURSE CURRICULUM

M. Sc. in Mathematics

SEMESTER-I

Sub. Code	Subject	L	T	P	Credit
MA-1101	Complex Analysis	3	0	0	3
MA-1102	Probability & Statistics – I	3	1	0	4
MA-1103	Programming Languages and Data Structure	3	1	0	4
MA-1104	Graph Theory	3	0	0	3
MA-1105	Linear Algebra and Calculus of Variations	3+2	0	0	3+2
MA -1106	Real Analysis	3	0	0	3
MA-1151	Programming Languages Lab	0	0	6	3

TOTAL CREDIT - 25

SEMESTER-II

Sub. Code	Subject	L	T	P	Credit
MA-2101	Modern Algebra	3	1	0	4
MA-2102	Integral Transforms and Integral Equations	3	0	0	3
MA-2103	Functional Analysis	3	1	0	4
MA-2104	Ordinary and Partial Differential Equations	3	1	0	4
MA-2105	General Mechanics	3	1	0	4
MA-2106	Numerical Analysis	3	1	0	4
MA-2151	Numerical Analysis Lab	0	0	4	2

TOTAL CREDIT - 25

SEMESTER-III

Sub. Code	Subject	L	T	P	Credit
MA-3101	Operations Research	3	1	0	4
MA-3102	Statistics - II & Stochastic Processes	3	1	0	4
MA-3103	Fluid Dynamics	3	1	0	4
	Elective-I	3	1	0	4
	Elective-II	3	1	0	4
MA-3151	Project –I	0	0	4	2
MA-3152	Seminar - I	0	0	2	1
MA-3153	Operations Research Lab	0	0	4	2

TOTAL CREDIT - 25

SEMESTER-IV

Sub. Code	Subject	L	T	P	Credit
MA-4101	Topology	3	1	0	4
MA-4102	Generalized Functions and Wavelets	3	1	0	4
	Elective-III	3	1	0	4
	Elective-IV	3	1	0	4
MA- 4151	Project – II	0	0	10	5
MA-4152	Seminar - II	0	0	4	2
MA-4153	Grand Viva	0	0	2	2

TOTAL CREDIT - 25

TOTAL COURSE CREDIT - 100

List of Electives

Sl. No.	Subject Code	Subject Name
1	MA 9111	Geophysics
2	MA9112	Nonlinear Waves
3	MA9113	Mathematical Modeling
4	MA9114	Advanced Complex Analysis
5	MA9115	Advanced Modern Algebra
6	MA9116	Automata and Algorithms
7	MA9117	Differential Geometry
8	MA9118	Optimization Techniques
9	MA9119	Fuzzy Mathematics
10	MA9120	Nonlinear Analysis
11	MA9121	Advanced Operations Research
12	MA9122	Algebraic Coding Theory
13	MA9123	Dynamical Systems and Chaos Theory
14	MA9124	Financial Mathematics
15	MA9125	Computational Fluid Dynamics
16	MA9126	Soft Computing
17	MA9127	Reliability Theory
18	MA9128	Multivariate Statistical Analysis
19	MA9129	Number Theory
20	MA9130	Cryptology

21	MA9131	Decision Theory

SUMMARY OF COURSES

Sub Discipline: DEPARTMENTAL CORE

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MA1101	COMPLEX ANALYSIS	3-0-0	4	Dr. S. Bagchi
MA1102	PROBABILITY & STATISTICS – I	3-1-0	4	Dr S.Maitra & Dr K.Basu
MA1103	PROGRAMMING LANGUAGES AND DATA STRUCTURE	3-1-0	4	Dr. Goutam Panigrahi
MA1104	GRAPH THEORY	3-0-0	3	Dr. A. Pal
MA1105	LINEAR ALGEBRA AND CALCULUS OF VARIATIONS	5-0-0	5	Dr.P.Pal & Dr.S.Maitra
MA1106	REAL ANALYSIS	3-0-0	3	DR L. K. DEY
MA2101	MODERN ALGEBRA	3-1-0	4	Dr. S. Bagchi
MA-2102	INTEGRAL TRANSFORMS AND INTEGRAL EQUATIONS			Dr. S. Maitra Dr. A.Pal
MA-2103	FUNCTIONAL ANALYSIS	3-1-0	4	DR L. K. DEY
MA-2104	ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS	3-1-0	4	Dr. P. Pal
MA-2105	GENERAL MECHANICS	3-1-0	4	Dr.S. Maitra
MA-2106	NUMERICAL ANALYSIS	3-1-0	4	Dr. S. Sarkar (Mondal) & Dr. A.Pal
MA-3101	OPERATIONS RESEARCH	3-1-0	4	Dr K.Basu & Dr. S.Sarkar (Mondal)
MA-3102	STATISTICS - II & STOCHASTIC	3-1-0	4	Dr K.Basu & Dr S Maitra

	PROCESSES			
MA-3103	FLUID DYNAMICS	3-1-0	4	Dr. P. Pal
MA-4101	TOPOLOGY	3-1-0	4	DR L. K. DEY
MA-4102	GENERALIZED FUNCTIONS AND WAVELETS	3-1-0	4	Dr. S. Maitra

Sub Discipline: DEPARTMENTAL ELECTIVES

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MA 9111	GEOPHYSICS	3-1-0	4	DR. S. SARKAR (MONDAL)
MA9112	NONLINEAR WAVES	3-1-0	4	Dr. S.Maitra
MA9113	MATHEMATICAL MODELING	3-1-0	4	Dr. S.Maitra
MA9114	ADVANCED COMPLEX ANALYSIS	3-1-0	4	DR S. BAGCHI
MA9115	ADVANCED MODERN ALGEBRA	3-1-0	4	DR L. K. DEY
MA9116	AUTOMATA AND ALGORITHMS	3-1-0	4	Dr. S. Kar & Dr. G. Panigrahi
MA9117	DIFFERENTIAL GEOMETRY	3-1-0	4	DR L. K. DEY
MA9118	OPTIMIZATION TECHNIQUES	3-1-0	4	DR. S.SARKAR (MONDAL)
MA9119	FUZZY MATHEMATICS			Dr. S. Kar
MA9120	NONLINEAR ANALYSIS	3-1-0	4	DR L. K. DEY
MA9121	ADVANCED OPERATIONS RESEARCH	3-1-0	4	Dr K.Basu
MA9122	ALGEBRAIC CODING THEORY	3-1-0	4	Dr S Bagchi & Dr L K Dey
MA9123	DYNAMICAL SYSTEMS AND CHAOS THEORY	3-1-0	4	Dr. P. Pal
MA9124	FINANCIAL MATHEMATICS	3-1-0	4	Dr.S.Maitra
MA9125	COMPUTATIONAL FLUID	2-0-2	4	Dr. P.Pal

	DYNAMICS			
MA9126	SOFT COMPUTING	3-1-0	4	Dr. S. Kar
MA9127	RELIABILITY THEORY	3-1-0	4	Dr. K. Basu
MA9128	MULTIVARIATE STATISTICAL ANALYSIS	3-1-0	4	Dr K.Basu
MA9129	NUMBER THEORY	3-1-0	4	Dr. S. Bagchi
MA9130	CRYPTOLOGY	3-1-0	4	Dr. S Bagchi
MA9131	DECISION THEORY	3-1-0	4	DR. S.SARKAR (MONDAL)

Sub Discipline: LABORATORY & SESSIONAL COURSES

MA-1151	PROGRAMMING LANGUAGES LAB	0-0-6	3
MA-2151	NUMERICAL ANALYSIS LAB	0-0-4	2
MA-3153	OPERATIONS RESEARCH LAB	0-0-4	2

Sub Discipline: PROJECT, SEMINAR etc.

MA-3151	PROJECT –I	0-0-4	2
MA-3152	SEMINAR - I	0-0-2	1
MA- 4151	PROJECT – II	0-0-10	5
MA-4152	SEMINAR - II	0-0-4	2
MA-4153	GRAND VIVA	0-0-2	2

DETAILED SYLLABI OF COURSES

SEMESTER-I

MA1101 Complex Analysis 3 credits [3-0-0]

Stereographic Projection, Analytic function, Cauchy-Riemann equations, Entire functions, Harmonic functions, Conformal Mappings, Fractional linear transformations. [7]

Line integrals and Green's Theorem, Harmonic conjugates. Complex line integrals, Cauchy's Theorem, Cauchy integral formula, Liouville's Theorem, Morera's Theorem, Goursat's Theorem. [12]

Power series expansion of an analytic function, Multiplication of power series, zeros of an analytic function, Laurent series and isolated singularities. Periodic function. [10]

Residues, Residue Theorem and its applications of proper and improper integrals. [6]

TEXT BOOKS:

1. **Gamelin, T. W.,** *Complex Analysis,* Springer, 2001.
2. **Ponnusamy, S.,** *Foundations of Complex Analysis,* Narosa Publishing House, 2011.

REFERENCE BOOKS:

1. **Ahlfors, L.V.,** *Complex Analysis,* McGraw-Hill, 1979.
2. **Donald J. Newman**, Joseph Bak, Complex Analysis, Springer, 2008.
3. **Rudin, W.,** *Real and Complex Analysis,* McGraw-Hill Book Co., 1966.

MA-1102 Probability and Statistics I 4 credits [3-1-0]

Probability:

Historical development of the subject and basic concepts, stochastic simulation, random numbers. [2]

Random variables and probability distributions, binomial and multinomial distribution, geometric distribution, hypergeometric distribution, normal distribution, gamma distribution, exponential distribution, negative binomial distribution. [4]

Simulations using Monte Carlo procedure, Buffon's needle problem, Two dimensional distribution, joint and marginal distribution, conditional distribution, random walks. [5]

Expected value and variance of a random variable, covariance, correlation. [3]

Distribution of sum of independent random variables, convergence of a sequence of random variables, convergence in distribution, convergence in probability, convergence in L^p, Tchebychev inequality, law of large numbers. [6]

Central limit theorem for Bernoulli trails, normal approximation to binomial, the general central limit theorem. [2]

Statistics I

Basic Concepts, rule, Measures of Central Tendency, Measures of Dispersion, Tchebycheff's theorem & Empirical rule Measures of relative standing, some principles of statistical model. [4]

Random Sampling & Methods of Sampling, Sampling Distribution & Standard Error, Sampling Distribution of the Sample Mean, Central Limit Theorem, Sampling Distribution of the Sample Proportion, sampling Distribution of the difference between two sample means and sampling Distribution of the difference between two sample proportions. [5]

Point Estimation, Interval Estimation, Confidence Interval, Large Sample Confidence Interval for a Population Mean μ, Large Sample Confidence Interval for a Population Proportion, estimating the difference between two Population means, estimating the Difference between two Binomial proportions, Maximum Likelihood Estimation. [4]

Statistical Hypotheses - general concepts, Large sample test about a population mean, Large sample test of Hypothesis for the Difference Between Two Population means, Large sample test for a Binomial proportion, Large sample test of Hypothesis for the difference between two Binomial proportions, Student's t-distribution, Small sample Inferences concerning a population mean, Inferences for the difference between two means, Inferences concerning a population variance, F-distribution, Comparing two population variances. [5]

Linear Regression, Properties of the Least Square Estimators, Inferences concerning the Regression coefficients, Analysis of variance for Linear Regression, Testing the usefulness of the Linear Regression Model. [5]

TEXT BOOKS:

1. **William Mendenhall, Robert J. Beaver, B.M. Beaver,** *Introduction to Probability & Statistics*. Twelfth Edition, India Edition, Thomson.
2. **Gary Smith**, *Essential statistics, Regression & Econometrics*, Second Edition.
3. C. Grinstead and J. Snell, Introduction to probability, American Mathematical Societ.

REFERENCE BOOKS:

4. **Montgomery,** *Applied Statistics and probability for Engineers. Fourth Edition,* Wiley India Pvt Ltd.
5. **Ronald E Walpole, Sharon L Myers & Keying Ye,** *Probability& Statistics for Engineers &Scientists.* Eighth Edition, Pearson

MA 1103 Programming Languages and Data Structure 4 credits [3-1-0]

Fundamentals of Computer: History of Computer, Generation of Computer, Classification of Computers. Basic Anatomy of Computer System, Primary & Secondary Memory, Processing Unit, Input & Output devices. Binary& Allied number systems representation of signed and unsigned numbers. BCD, ASII. Binary Arithmetic & logic gates. Basic concepts of operating systems like MS DOS, MS WINDOW, UNIX, Algorithm & flow chart. [6]

C Fundamentals: The C character set identifiers and keywords, data type & sizes, variable names, declaration, statements. [2]

Operators &Expressions: Arithmetic operators, relational and logical operators, type, conversion, increment and decrement operators, bit wise operators, assignment operators and expressions, precedence and order of evaluation. Input and Output: Standard input and output, formatted output -- printf, formatted input scanf. [4]

Flow of Control: Statement and blocks, if - else, switch, loops - while, for do while, break and continue, go to and labels. [6]

Fundamentals and Program Structures: Basic of functions, function types, functions returning values, functions not returning values, auto, external, static and register variables, scope rules, recursion, function prototypes, C preprocessor, command line arguments. [4]

Arrays and Pointers: One dimensional arrays, pointers and functions, multidimensional arrays. [2]

Structures Union and Files: Basic of structures, structures and functions, arrays of structures, bit fields, formatted and unformatted files. [6]

Data Structures: Arrays, Stacks Queues, Searching & Sorting Algorithms. [8]

Trees: Traversals in a tree, Binary Search tree, B^+ tree, B tree. [7]

TEXT BOOKS:

1. **V. Rajaraman,** *Computer Programming in C*, Prentice Hall India, 1994.
2. **Seymour Lipschutz " Data Structures"** McGraw-Hil**l 1986.**

REFERENCE BOOKS:

3. **E. Balagurusamy,** *Introduction to Computing*, TMH.
4. **F. S. Schied,** *Theory and Problems of Computers and Programming.*

MA 1104 **Graph Theory** **4 credits [3-1-0]**

Graph Theory:

Definition of graph, Basic terminology, Directed graphs and weighted graphs, Types of graphs, Graph isomorphism, Sum and product of graphs, Components, Connected and disconnected graphs, Euler path, Euler circuit and Euler theorem, Hamiltonian path and circuit. [4]

Trees: Definition, Properties of trees, Distance, radius, diameter and centre of graphs and trees, Binary tree, Binary tree traversal, Application. [4]

Planar graphs: Definition, Planar and non-planar graphs, Kuratowaski's two graphs, Homeomorphic graphs, Geometric and combinatorial duals, Applications of planar graphs. [4]

Cut-set and cut-vertices: Definition of cut-set and cut-vertices, Rank and nullity, Fundamental circuits and fundamental cut-sets, Connectivity and separability,Cut-edge and bridge, Network flow problem, Maxflow –mincuttheorem, Applications. [5]

Colouring and Matching: Definition, Chromatic number and Chromatic polynomial, Bipartite graph, Chromatic partitioning, Matching and its application, Covering, Five-colour and Four- colour theorems, Applications. [5]

Graph Algorithms: Matrix representation of graphs, Asymptotic notations, O, o, , , etc., Shortest path algorithms: Dijkstra and Floyd's algorithms, Spanning tree and minimum spanning tree, Prim's and Kruskal's algorithms to find spanning tree, Binary tree traversal, DFS and BFS of a graph. [6]

Intersection graphs: Interval graph, PQ tree, Circular-arc graphs, Permutation graphs, Trapezoid graphs, Perfect graphs, -perfect and -perfect,Chordal graphs, Applications. [4]

Applications of graphs: in Operations Research, Chemistry, Planning, Biological Sciences. [3]

TEXT BOOKS:

1. **Narsingh, Deo,** *Graph Theory with Applications to Engineering and Computer Science,* Prentice-Hall of India.
2. **Douglas B. West,** *Introduction to Graph Theory*, PHI, New Delhi.

REFERENCE BOOKS:

1. **Kolman and R.C. Busby,** *Discrete Mathematical Structures for Computer Science*, PHI, New Delhi, 1994.
2. **M. C. Golumbic,** *Algorithmic Graph Theory and Perfect Graphs,* 2ed, Elsevier.

MA 1105 Linear Algebra & Calculus of Variations 5 credits [5-0-0]

Linear Algebra:

Vector Spaces and Linear Transformations: Vector Spaces over fields, subspaces, bases and dimension. Linear transformations, the algebra of linear transformation, Rank of a linear transformation, matrix representations, and rank-nullity theorem. [8]

Linear System and Matrix Theory: Matrices and algebra of matrices, system of linear equations, geometric meaning of linear systems, some standard methods for solving linear systems. Characteristic polynomial, Eigen value, Eigen vectors, properties of characteristic polynomial and some consequences. Diagonalization, Invariant Subspaces, and Cayley-Hamilton Theorem. [9]

Canonical Forms: Similarity of linear transformations, and Reduction to Triangular Forms. Nilpotent Transformations, Index of Nilpotency, Invariants of a nilpotent transformation, Jordan Blocks and Jordan Forms, Rational Canonical Form. [9]

Inner Product Space: Orthogonality in R^n, orthogonal compliment, orthogonal projections, Gram-Schmidt Orthogonalization Process, Bilinear and quadratic forms. [9]

Calculus of Variations

Variation and its properties: Euler's equation, Brachistochrone problem, shortest distance between two points, Curves of minimum arc of surface of revolution.

Geodesics: Geodesics in spherical polar and cylindrical coordinates, Functional dependent on higher order derivatives, Variational problems involving several unknown functions, Functional involving

several independent variables-Ostrogradsky equation, Optimization under constraints and Lagrange multipliers.

Isoperimetric Problems: Isoperimetric problems involving constraints as functional Variational problems with moving boundaries, Transversality conditions.

Lagrange's Equations: Lagrange's equations for dynamical systems, Hamilton's principle, Sturm-Lioville's problem and variational methods, Raleigh's principle, Direct methods of Ritz and Kantorovich methods, Applications.

TEXT BOOKS:

1. **S. H. Fridberg, A. J. Insel& L.E. Spence,** *Linear Algebra*, PHI (1994).
2. **K. Hoffman & Ray Kunze**, *Linear Algebra*, Prentice Hall, India (1972).
3. **A. S. Gupta,** *Calculus of Variations with Applications*, PHI. 2005.

REFERENCE BOOKS:

1. **P. Halmos**, Finite-Dimensional Vector Spaces, Springer-Verlag, New York (1987).
2. **S. Roman,** Advanced Linear Algebra, Springer (2005).
3. **I. M. Gelfand and S. V. Fomin**, *Calculus of Variations*, Prentice-Hall, New Jersy, 1963.

MA1106 REAL ANALYSIS 3 credits [3-0-0]

Functions of bounded variation and their properties, differentiation of a function of bounded variation, Absolutely Continuous Function, Representation of an absolutely continuous function by an integral. [6]

Riemann integral and its properties, characterization of Riemann integrable functions. Riemann-Lebesgue Lemma, Drawbacks of Riemann Integral, Lebesgue's recipe, Riemann-Stieltjes integral. [6]

Semi ring and ring of sets, σ-ring and σ-algebra, Ring and σ-ring generated by a class of sets, Monotone class of sets, Monotone class generated by a ring, Borel Sets. Outer Measure and Measurable Sets, Lebesgue measure on R^n, Measure space, Measurable Functions, Sequence of measurable functions, Egorov's Theorem, Convergence in Measure. [15]

Integrating Bounded Measurable Functions, Criteria for Integrability and Properties of the Lebesgue Integral, Comparison of Lebesgue and Riemann Integrals. [8]

TEXT BOOKS:

1. **Charles Chapman Pugh,** *Real Mathematical Analysis*, Springer.

2. **Kolmogorov A. N., Fomin, S. V.,** *Measures, Lebesgue Integrals, and Hilbert Space*, Academic Press, New York & London, 1961.

REFERENCE BOOKS:

4. **Aliprantis C. D., Burkinshaw O.,** *Principles of Real Analysis*, 3rd Edition, Harcourt Asia Pte Ltd., 1998.
5. **Royden H. L.,** *Real Analysis*, 3rd Edition, Macmillan, New York & London, 1988.
6. **T. Apostol,** *Mathematical Analysis*, 2nd Ed., Narosa Publishers, 2002.

Lab-I: Programming Languages Lab (MA 1151)

C Language:

Execution of Programs using the following: Decision Making and Branching- if statement, Nested if, Else if ladder, Block if, Switch statement. Decision Making and looping-while, do-while, for. Arrays- Traversing, Sorting, Searching, Inserting, Deleting operations; Processing Arrays with more than one dimension, Functions, Recursive functions, Nesting of Functions. Structures- Use of structure, Array of Structures, Unions, Handling Files in C- Sequential, random access files. Use of Pointers, Linked Lists: Linear one-way linked list- Traversing, Insertion, Deletion and Searching operations. Use of Preprocessors: Simple Preprocessors- Macro substitutions, File inclusion directives.

MATLAB:

Introduction: Editor, Debugger, Simulink, Web resources, Toolboxes.

Function Minimization and parameters search: Polynomial fit, 1D and 2D fits, Data windowing, Error bounds, Arbitrary function fit, Error function, Fixing parameters, Goodness of fit, Bicriteria, Error in parameters.

Dataflow in Matlab: Data types, Matrix, string, cell and structure, Creating, accessing elements and manipulating of data of different types, File Input-Output, Matlab files, Text files, Binary files, Mixed text-binary files, Communication with external devices, Serial port, Parallel port, Sound card, Video input.

Numerical Methods and Applications: Roots of equations, Algebraic and transcendental equations, System of linear equations, Application.

Differential equations: Euler method, RK (ODE45), SIMULINK.

SEMESTER-II

MA 2101 Modern Algebra 4 credits [3-1-0]

Preliminary concept: Sets and Equivalence relations and partitions, Division algorithm for integers, primes, unique factorizations, Chinese Remainder Theorem, Euler ϕ-function. [7]

Groups: Cyclic groups, Permutation groups, Isomorphism of groups, Cosets and Lagrange's Theorem, Normal subgroups, Quotient groups, Group Homomorphisms, Cayley's Theorem, Cauchy's Theorem, Group Action, Sylow Theorems and their applications. [15]

Rings: Ideals and Homomorphism, Prime and Maximal Ideals, Quotient Field of an Integral Domain, Polynomial and Power Series Rings. [10]

Divisibility Theory: Euclidean Domain, Principal Ideal Domain, Unique Factorization Domain. [7]

Fields: Field extensions, Algebraic extensions, Finite Fields. [6]

TEXT BOOKS:

1. **G. A. Gallian,** *Contemporary Abstract Algebra,* Narosa Publishers, 2013.
2. **I. N. Herstein,** *Topics in Abstract Algebra*, Wiley Eastern Limited, 1975.

REFERENCE BOOKS:

1. **T. W. Hungerford,** *Algebra,* Springer, 2009.
2. **D. S. Dummit, R. M. Foote,** *Abstract Algebra,* Second Edition, John Wiley & Sons, Inc., 1999.
3. **J. B. Fraleigh,** *A First Course in Abstract Algebra,* Addison Wesley, 2013.

MA2102 Integral Transforms & Integral Equations 3 credits [3-0-0]

Fourier Integrals and Fourier Transforms: Fourier Integral Representation, Fourier Integral Theorem, Different forms of Fourier Integrals, Fourier Transform and Inverse of Fourier Transform, Fourier Sine and Cosine transforms and their inverse Transforms, Complex Fourier Transform and its inversion formula, Properties of Fourier Transform, Fourier Transforms for functions of many variables, Perseval's Relations. Application to ODE & PDE. [6]

Laplace Transforms: Definition of Laplace Transform, Existence Theorem, Properties of Laplace Transform, Laplace Transform of Derivatives, Laplace Transform of Integrals, Special techniques for

finding Laplace Transform, Inverse of Laplace Transform, Properties of Inverse Laplace Transforms, Partial Fraction method for finding the Inverse of Laplace Transform, Application to ODE. [6]

Henkel Transform: Properties of Henkel Transform, Evaluation of Henkel Transform. [2]

MellinTransform: Properties of Mellin Transform, Evaluation of Mellin Transform. [2]

Z – Transform: Definition of Z- transform, Properties of Z – Transform, Z – Transform of some standard functions, Theorems on Z – transform, Differentiation, Convolution Theorem, Inverse Z – Transform and different methods for finding Inverse Z – transforms. [4]

Integral Equations: Formulation of Integral Equations, Classification of Integral equations, Volterra's equation of second kind, Solution of Volterra's equation of Second kind, Solution of Volterra's equation of First kind, Method of Resolvent kernels, Cauchy kernel, Abel Equation, Fredholm's Integral Equations, Fredholm's Singular equations, Eigen values and Eigen functions of Integral equation, Properties of Eigen values and Eigen functions, Fredholm's Theorem, Integro-differential equations. [15]

TEXT BOOKS:

1. **I. N. Sneddon,** *The Uses of Integral Transforms, McGraw-Hill.*
2. **Andrews & Shivamoggi,** *Integral Transforms for Engineers, PHI.*
3. **P. R. Kanwal**, *Integral equations,* Springer.

REFERENCE BOOKS:

1. **B. Bhattacharya,** *Mathematical Physics,* NCBA Books.
2. **C. J. Tranter,** *Integral Transforms, Methuen & Co.*
3. **Lovitt,** *Linear Integral Equations, Dover Publications Inc.*

MA2103 **FUNCTIONAL ANALYSIS** **4 CREDITS [3-1-0]**

Metric space: Definitions and examples; spaces like $l^p, l^\infty, C[a,b]$. Continuity and equivalent metrics, compactness, Cauchy sequences, completeness and completion of metric spaces. [10]

Banach Spaces: Normed Linear Spaces, Banach Spaces, Equivalent Norms, Finite dimensional normed linear spaces, Riesz Lemma, Banach's Fixed Point Theorem and its applications. [8]

Bounded Linear Transformations, Normed linear spaces of bounded linear transformations, Uniform Boundedness Theorem, Open Mapping Theorem, Closed Graph Theorem, Linear Functionals, Hahn-Banach Theorem, Dual Space, and Reflexivity of Banach Spaces. [12]

Hilbert Spaces: Real Inner Product Spaces and its Complexification, Cauchy-Schwarz Inequality,

Parallelogram law, Pythagorean Theorem, Hilbert Spaces, Orthonormal Sets, Complete Orthonormal Sets, Structure of Hilbert Spaces, Orthogonal Complement and Projection Theorem. [8]

Riesz Representation Theorem, Adjoint of an Operator on a Hilbert Space, Reflexivity of Hilbert Spaces, Self-adjoint Operators, Positive Operators, Projection Operators. [6]

TEXT BOOKS:

1. **Kreyszig E.,** *Introductory Functional Analysis with Applications*, John Wiley and Sons, New York.
2. **Bachman G., Narici, L.,** *Functional Analysis*, Dover Publications Inc.; 2nd edition (2003).

REFERENCE BOOKS:

1. **Conway J. B.,** *A Course in Functional Analysis*, Springer Verlag, New York, 1990.
2. **Goffman C., Pedrick G.,** *First Course in Functional Analysis*, Prentice Hall of India, New Delhi, 1987.
3. **S. Ponnusamy,** *Foundations of Functional Analysis*, Narosa Publishing House.

MA2104 Ordinary and Partial Differential Equations 4 CREDITS [3-1-0]

Ordinary Differential Equations:

Review of solution methods for first order as well as second order equations: Existence and Uniqueness of solution, Initial Value Problems, Existence and Uniqueness theorem, Lipschitz condition, Series solution around ordinary point and a regular singular point, Bessel functions and Legendre polynomials. [10]

Higher Order Linear Equations and linear Systems: Fundamental solutions, Wronskian, variation of constants, matrix exponential solution, behavior of solutions. [2]

Boundary Value Problems for Second Order Equations: Green's function, Sturm Liuville problems, Perturbation theory for two-dimensional linear system. [10]

Partial Differential Equation:

Cauchy Problems for First Order Hyperbolic Equations: Method of characteristics. Classification of Second Order Partial Differential Equations: normal forms and characteristics. Initial and Boundary Value Problems: Lagrange-Green's identity and uniqueness by energy methods. Stability theory, energy conservation and dispersion. [12]

Laplace equation: Mean value property, weak and strong maximum principle, Green's function, Poisson's formula, Dirichlet's principle, existence of solution using Perron's method (without proof).

[8]

Heat equation: Initial value problem, fundamental solution, weak and strong maximum principle and uniqueness results. Wave equation: uniqueness, D'Alembert's method, method of spherical means and Duhamel's principle. Methods of separation of variables for heat, Laplace and wave equations. [4]

Reference Books:

1. **Shepley L. Ross,** *Differential Equations*, Wiley, 1984.
2. **F. John**, Partial Differential Equations, 3rd ed., Narosa Publ. Co., New Delhi,1979.

Reference Books:

3. **E. A. Coddington, and N. Levinson,** *Theory of Ordinary Differential Equations,* Tata McGraw Hill, 1990.
4. **E. DiBenedetto,** *Partial Differential Equations,* Birkhauser, Boston, 1995.
5. **L. C. Evans**, *Partial Differential Equations,* Graduate Studies in Mathematics, Vol. 19, AMS, Providence, 1998.
6. **I. N. Sneddon,** *Elements of Partial Differential Equations,* McGraw Hill, 1957.

MA2105 General Mechanics 4 Credits [3-1-0]

Moving coordinates systems, Gallilean transformation, inertial and noninertial frames of reference. [2]

Constrained motions in Cartesian coordinates, Principle of virtual work, D'Alembert's principle. [2]

Degrees of freedom, generalized coordinates, Lagrange's formulation in generalized coordinates, generalized forces, cyclic coordinates [6]

Canonically conjugate coordinates and momenta, Legendre transformation, Hamiltonian [3]

Principle of least action, Hamilton's principle, Hamilton's equations of motion, Two body central force problem, Symmetry properties and conservation laws, Noether's theorem [8]

Canonical Transformation, Generating function, Poisson bracket, Identities on Poisson brackets, Hamilton-Jacobi theory, Solution of the Hamilton –Jacobi equation [8]

Planck's law, Photo electric effect, Bohr's theory, Compton effect, de Broglie waves; Wave-particle dualism, Uncertainity Principle, Path integrals, Fundamental laws and foundation of quantum mechanics. Schrodinger equation. [9]

The Continuum hypothesis, Analysis of strain and stress; Concepts of body forces/surface forces, Stress-strain relations [7]

TEXT BOOKS:

1. **H. Goldstein,** *Classical Mechanics,* Narosa Publication, New Delhi, 1998.
2. **David J. Griffiths,** *Introduction to Quantum Mechanics,* Pearson Education.

REFERENCE BOOKS:

1. **L. Landau, E. Lifshitz,** *Mechanics,* Pergamon Press.
2. **N. C. Rana and P. S. Joag,** *Classical Mechanics,* Tata McGraw Hill, New Delhi, 2002.

MA 2106 Numerical Analysis 4 CREDITS [3-1-0]

Finite Difference and Interpolation: Symbolic operators and their relations, Difference table, Central difference formulae of Gauss, Stirling formula, Bessel formula, Cubic spline interpolation. [5]

Approximation of function: Curve fitting by least square method (linear, polynomial, geometric), Chebyshev polynomial and Minimax property, Use of orthogonal polynomials, Gram-Schmidt orthogonalization method, Economization of power series. [4]

Numerical integration: Newton-Cotes formulae-open type and closed type, Romberg integration, Gaussian quadrature: Gauss-Legendre and Gauss-Chebyshev quadratures, Comparison of Newton-Cotes and Gaussian quadratures. [5]

Solution of non-linear equations: Roots of a polynomial by Birge-Vieta method, Graeffe's root squaring method, System of non-linear equations: fixed point method and Newton-Raphson methods, Convergence and rate of convergence. [6]

Solution of a system of linear equations: Matrix inversion method by partial and complete pivoting, LU decomposition method, Solution of tri-diagonal system of equations, Ill-conditioned linear systems, Relaxation method. [7]

Eigenvalue problem: Power method to find largest eigen value of eigen vector, Jacobi's method to find eigen values and eigen vectors of a symmetric matrix. [4]

Solution of ordinary differential equation: Taylor's and Euler's method, Runge-Kutta method of second and fourth order, Runge-Kutta method to solve a system of equations, Single step and multi-step methods, Predictor-corrector method: Milne's method, Adam's method, Solution of boundary value problems by finite difference method, Stability analysis. [8]

Partial differential equation: Finite difference scheme, Parabolic equation: Crank-Nicolson method, Elliptic and hyperbolic equations: iteration method. [6]

TEXT BOOKS:

1. **J.H. Mathews & K.D. Fink,** *Numerical Methods, Prentice Hall.*
2. **M.K. Jain, S.R.K. Iyengar & R.K. Jain**, *Numarical Methods, New Age International Publishers.*
3. **S. S. Sastry,** *Introductory Methods of Numerical Analysis, PHI.*

REFERENCE BOOKS:

1. **C. Butcher,** *Numerical Methods for Ordinary Differential Equations, Wiley*
2. **J.B. Scarborough**., *Numerical Mathematical Analysis, Oxford and IBH publishing co.*

MA 2151 Numerical Analysis Lab. 2 CREDITS [0-0-4]

Using C and C++:

Solution of system of linear equations Matrix inversion, L-U decomposition methods.

Determination of Eigen value, Eigen vectors by Jacobi's method.

Interpolation: - Newton's forward and backward interpolation, Langrange's interpolation, Central difference interpolation, cubic spline interpolation.

Numerical integration by trapezoidal rule, Simpson's $1/3^{rd}$ rule, Gauss Quadrature formulae.

Solution of ODE by Runge-kutta method and Milne's Predictor-corrector method.

Solution of PDE by finite difference method.

SEMESTER-III

MA 3101 Operations Research 4 credits [3-1-0]

Extension of Linear Programming: Revised Simplex, Bounded Variables, Dual Simplex, Sensitivity Analysis. [10]

Integer Programming: Branch and bound algorithm, Cutting plane methods for pure and mixed Integer programming problems, Knap-sack problem, travelling salesman problem. [6]

Dynamic Programming: Bellman's principle of optimality and recursive relationship of dynamic programming for various optimization problems. [6]

Deterministic Inventory Management:

Concept of inventory and various inventory parameters, EOQ formula, EOQ with quantity discount, Multi-item Inventory and Multiple Constraints, Inventory with deterministic non-constant demand rate, Concept of Lead time, safety stock and service level. [5]

Game Theory: Maxmin and Minmax principle, two –person Zero-sum games with saddle point. Game problems without saddle point, Pure strategy, Solution of a 2 × 2 game problem without saddle point, Graphical method of solution for n ×2 and 2 ×n game problem, Reduction rule of a game problem(Dominance rule), Algebraic method of solution of game problem without saddle point, Reduction of a game problem to linear programming problem.

Bimatrix games: LCP formulation, Lemke's salgorithm for solving bimatrix. [8]

Network Analysis: Introduction to network analysis, Shortest path problem, Construction of minimal spanning tree, Flows in networks, Maximal flow problems.

Definition of a project, Job and events, Construction of arrow diagrams, Determination of critical paths and calculation of floats. Resource allocation and least cost planning, Use of network flows for least cost planning. Uncertain duration and PERT, PERT COST system. Crashing, Updating (PERT and CPM).

[10]

Text Books:

1. **J.K.Sharma:***Operations Research- Theory and applications*. Macmillan.
2. **Ravindran, Philips, Solbery:** *Operations Research- Principals and practice*.John Wiley & Sons.
3. **E.N.Barron** " *Game Theory an Introduction*" John wiley & sons publication.

Reference Books:

1. **Kanti Swarup, P. K. Gupta and Manmohan:** *Operations Research*. S.Chand & Sons.
2. **F.S.Hiller & G.J.Leiberman:** *Introduction to Operations Research*, Gc Graw Hill.

MA 3102 Statistics - II & Stochastic Processes 4 Credit [3-1-0]

Statistics – II:

Designing & Analyzing of single factor experiments: The Design of an Experiment, The Completely Randomized Design-A one –way classification, ANOVA for a completely Randomized design, random effects model, The Randomized Block Design- a Two-way classification, ANOVA for a Randomized Block Design. [4]

Design Of experiments with several factors: Factorial experiments, two factor factorial experiments, general factorial experiments, 2^k factorial experiments. [4]

Regression Analysis Revisited: Multiple regression**,** multiple correlation. multiple correlation coefficient in terms of partial correlation coefficient, Testing the significance of the regression coefficients, Testing of linear hypothesis, Bias in the regression estimators due to choice of wrong model. [4]

Non-Parametric Statistics: Wilcoxon Rank sum list: Independent random samples. The sign test for a paired experiment. A comparison of statistical tests, Wilcoxon signed- rank test for a paired experiment, The Kruskal-Wallis H-test for Completely Randomized Design. [4]

Analysis of categorical data: Chi-square statistic, The goodness of fit test, The chi-square test of significance, Contingency tables: A two way classification, ways of comparing proportions, Measures of associations. [3]

Statistical Quality Control: Objectives of Quality Control, Causes of Variation in quality, Techniques of SQC, Control charts for Variables ($\bar{X}$-charts & R-chart S-chart & σ -chart), 6σ concept, Control charts for Attributes (p-charts, np-chats, C-charts),Statistical process control, Terms used in sampling Inspection plans. [4]

Stochastic Processes:

Stochastic Processes: Description & Specification of Stochastic Process, Stationary Processes, Martingales.

Markov Chains: Definitions, Chapman-Kolmogorov Equations & classification of states, Applications of Markov chains, Time reversible Markov chains.

Poisson Process: Poisson Process, Inter-arrival & waiting time distributions, Non-homogeneous Poisson Process, Conditional Poisson process.

Continuous time Markov chains: Continuous time Markov chains, Birth &Death Processes, Kolmogorov differential equations, Randomization.

Random walks: Duality in random walks, Use of Martingales to analyze random walks

Markov Processes with continuous state space: Brownian motion, wiener process, differential equations for a wiener process, Kolmogorov equations

Renewal Theory: Renewal process, renewal processes in continuous time, Renewal equation, stopping time.

TEXT BOOKS:

1. **William Mendenhall, Robert J. Beaver, B.M. Beaver,** *Introduction to Probability & Statistics.* Twelfth Edition, India Edition, Thomson.
2. **D.C.Montgomery & G.C.Runger**,*Applied statistics and probability for engineers*, Wiley Asia students edition.

REFERENCE BOOKS:

1. S.M. Ross, *A first course in probability*, Macmilan**.**

2. J. Medhi, *Stochastic Processes* (New age International).

3. **D. C. Montgomery**, *Design of experiments*; Wiley Asia students edition.

MA 3103 Fluid Dynamics 4 credits [3-1-0]

Review of gradient, divergence and curl. Elementary idea of tensors. [4]

Velocity of fluid, Streamlines and path lines, Steady and unsteady flows, Velocity potential, Vorticity vector, Conservation of mass, Equation of continuity. Equations of motion of a fluid, Pressure at a point in fluid at rest, Pressure at a point in a moving fluid, Euler's equation of motion, Bernoulli's equation.

[10]

Singularities of flow, Source, Sink, Doublets, Rectilinear vortices. Complex variable method for two-dimensional problems, Complex potentials for various singularities, Circle theorem, Blasius theorem, Theory of images and its applications to various singularities. [12]

Three dimensional flow, Irrotational motion, Weiss's theorem and its applications. Viscous flow, Vorticity dynamics, Vorticity equation, Stress and strain analysis, Navier-Stokes equation, Some solutions of Navier-Stokes equations. [12]

Dimensional Analysis, Reynolds number, Boundary layer Equations. [7]

TEXT BOOKS:

1. **F. Chorlton,** *A Text Book of Fluid Dynamics,* Von Nostrand Reinhold/CBS, 1985.
2. **P. K. Kundu, I. M. Kohen, and D. R. Dowling,** *Fluid Mechanics,* Academic Press, 2011.

REFERENCE BOOKS:

1. **G. K. Batchelor,** *An Introduction to Fluid Dynamics,* Cambridge University Press, 1993.
2. **A. J. Chorin, and J. E. Marsden,** *A Mathematical Introduction to Fluid Mechanics,* Springer, 2000.
3. **L. D. Landau, and E. M. Lifshitz,** *Fluid Mechanics,* Pergamon Press, 1987.

Lab-III: Operations Research Lab (MA 3153)

The following problems are to be solved by using C/C^{++} language:

Problems on LPP by Simplex Method.

Problems on LPP by Revised Simplex Method.

Problems on Integer Programming by Gomory's cutting plane method.

Problems on Networking (PERT and CPM).

Problems on Inventory.

Problems on Dynamic Programming.

Problems on Monte Carlo Simulation.

Problems on Queuing Theory.

Problems on Bi-matrix games.

Problems on QPP by Beals's Method and Wolfe's Method.

SEMESTER-IV

MA4101 TOPOLOGY 4 CREDITS [3-1-0]

Set Theory: Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem, Cardinal Numbers and Cardinal Arithmetic, Continuum Hypothesis, Zorn's Lemma, Axiom of Choice, Well-Ordered Sets, Maximum Principle, Ordinal Numbers. [8]

Topological Spaces and Continuous Functions: Topological spaces, Basis and Subbasis for a topology, Order Topology, Product topology on $X \times Y$, subspace Topology, Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set, Continuous Functions, Open maps, Closed maps and Homeomorphisms, Product Topology, Metric Topology, Characterization of compact metric spaces, equicontinuity, Ascoli-Arzela Theorem, Baire Category Theorem. Baire Category Theorem, Applications: space filling curve, nowhere differentiable continuous function. [16]

Connectedness and Compactness: Connected and Path Connected Spaces, Connected Sets in R, Components, Local Connectedness. Compact Spaces, Compact Sets in R, Heine-Borel Theorem, Local –compactness, Compactness in Metric Spaces. [11]

Countability and Separation Axioms: Countability Axioms, The Separation Axioms, Lindelöf spaces, Regular spaces, Normal spaces, Urysohn Lemma, Tietze Extension Theorem, One-point Compactification. [10]

TEXT BOOKS:

1. **Munkres, J.R.,** *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. **Simmons, G.F**., *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.

REFERENCE BOOKS:

1. **Dugundji, J.,** *Topology*, Allyn and Bacon, 1966.
2. **Kelley, J.L.,** *General Topology*, Van Nostrand Reinhold Co., New York, 1995.
3. **Hocking, J., Young, G.,** *Topology*, Addison-Wesley Reading, 1961.

MA 4102 Generalized Functions and Wavelets 4 Credits [3-1-0]

Generalized functions: Test functions, distributions, delta function, delta sequence, Green's function using delta function, Heaviside function, derivative of a generalized function, Laplace transform of

distribution, distribution solution of ordinary and partial differential equations [20]

Wavelets: Basics of Fourier transform, Gibb's phenomenon, windowed Fourier transform, Filters, Wavelet, Wavelet transform, scaling functions, Haar wavelets, Haar decomposition and reconstruction Multiresolution analysis, properties of scaling functions, decomposition and reconstruction algorithm, filters and diagrams, Daubechies wavelets and its construction, Applications of wavelet analysis, numerical solution of a partial differential equation using wavelets. [25]

TEXT BOOKS:

1. **V.S. Vladimirov,** *Methods of the theory of generalized functions,* Taylor and Francis.
2. **C.K. Chui,** *An introduction to Wavelets,* Academic Press.

REFERENCE BOOKS:

1. **R.S. Pathak,** *Wavelet Transform,* Atlantis Press/World Scientific.
2. **D.S. Jones**, *Generalised functions,* Mc Graw-Hill publishing company limited.

List of Electives

MA9111 **Geophysics** **4 credits [3-1-0]**

Pre-requisite: Analysis of strain, infinitesimal strain, Analysis of stress, Concepts of body forces/surface forces, Stress- strain relations, Hooke's law, Lame elastic parameters, Young's modulus, Bulk modulus, Stress equation of motion. [10]

Theory of Elastic waves: Body waves and surface waves, P-& S-waves and their characteristics, Rayleigh waves, Stonely waves, Love waves in layered media, Dispersion and Amplitude of seismic waves, Reflection and refraction of seismic waves. [12]

Ray theory: Travel time analysis. [5]

Internal constitution of the Earth: Seismic method of Geophysical Prospecting, Reflection shooting and refraction shooting. Source Mechanism: Lamb's problem, Representation theorem, seismic Tomography, Inverse Problem. Theory of Continental Drift & plate Tectonics. [10]

Earthquake Scales: Magnitude & Intensity scales, Determination of focus of an earthquake. Microseism, Tsunami, Foreshock, Aftershock. [8]

TEXT BOOKS:

1. **William Lowrie,** *Fundamentals of Geophysics,* Cambridge University Press, UK.
2. **K. E. Bullen and Bruce A. Bolt,** *An Introduction to the Theory of Seismology,* Cambridge University Press, UK.
3. **Markus Bath,** *Mathematical Aspects of Seismology,* Elsevier Publishing Company.

REFERENCE BOOKS:

1. **W.M. Ewing, W.S. Jardetzky, F. Press,** *Elastic Waves in layered Media,* McGraw Hill Book Company, NY.
2. **Fung & Tong,** *Classical and Computational Solid Mechanics,* World Scientific.
3. **Kasahara, K**.,*Earthquake Mechanics,* Cambridge University Press.

MA9112 **Nonlinear Waves** **4 Credits [3-1-0]**

Theory of nonlinear waves: Dispersive and nondispersive waves, Fourrier transform method, shallow water waves, deep water waves, K-dv equation and its solutions, soliton and its properties, conservation laws, Lax pair, reaction-diffusion systems, dissipative waves. [15]

Perturbative methods: Regular and singular perturbation, phase space methods. [6]

Introduction to plasma dynamics: Basics of plasma, quasineutrality, Debye length, mobility of charge particles, effect of magnetic field, diffusion of electrons and ions, ambipolar diffusion, dielectric constant of a plasma, optical properties of a plasma, electrostatic and electromagnetic waves in a plasma, Fluid dynamic theory of plasma. [18]

Kinetic theory of plasmas: Particle distribution function, Boltzmann-Vlasov equation, Vlasov Maxwell equations. [6]

TEXT BOOKS:

1. **E. Infeld, G.Rowlands,** *Nonlinear waves, solitons and chaos,* Cambridge University Press, UK.
2. **F. F. Chen,** *Introduction to Plasma Physics,* Plenum Press, New York and London.

REFERENCE BOOKS:

1. **P.L. Bhatnagar**, *Nonlinear waves in one dimensional dispersive systems,* Oxford University Press.

MA 9113 Mathematical Modeling 4 Credits [3-1-0]

Basics of Mathematical Modeling: Elementary mathematical models; Role of Mathematics in problem solving; Concept of mathematical modeling; System approach; formulation, analysis of models; Sensitivity analysis. [4]

Mathematical Modeling through ordinary differential equations: Linear growth and decay model, Nonlinear growth and decay models (Logistic law of population growth). [4]

Mathematical Modeling through system of ordinary differential equations of first order: Prey-Predator models, Mathematical modeling of epidemics. [10]

Mathematical Modeling through Difference equations: Mathematical modeling in population dynamics and genetics, Mathematical modeling in probability theory. [9]

Mathematical Modeling through partial differential equations: PDE model for birth-death immigration-emigration process, PDE model for a stochastic epidemic process with no removal. [8]

Mathematical modeling through stochastic Differential Equations: Brownian motion and its properties, Ito formula, Ito integrals and its properties, Comparison between Ito and Stratonovich integrals. [10]

TEXT BOOKS:

1. **J. N. Kapur,** *Mathematical Modeling,* Wiley Eastern.
2. **B. K. Oksendal,** *Stochastic differential equations, An introduction with applications,* Springer.

REFERENCE BOOKS:

1. **J.D. Logan and W.R.Wolesensky**, *Mathematical methods in biology,* Wiley.

MA9114 Advanced Complex Analysis 4 CREDITS [3-1-0]

Mobius transformations, conformal mappings, Hurwitz theorem, Rouche's theorem, Open Mapping Theorem, The Schwarz lemma, Automorphisms of the disk, Infinite product, The Mittag-Leffler Theorem, Factorization of Entire functions, Analytic continuation, The Schwarz Symmetry Principle, Normal families and Montel's theorem, The Riemann mapping theorem. [45]

TEXT BOOKS:

1. **Gamelin, T. W.,** *Complex Analysis,* Springer, 2001.

2. **Ahlfors, L.V.,** *Complex Analysis,* McGraw-Hill, 1979.

REFERENCE BOOKS:

1. **Ponnusamy, S.,** *Foundations of Complex Analysis,* Narosa Publishing House, 2011.
2. **Donald J. Newman**, Joseph Bak, Complex Analysis, Springer, 2008.
3. **Rudin, W.,** *Real and Complex Analysis,* McGraw-Hill Book Co., 1966.

MA4101 ADVANCED MODERN ALGEBRA 4 CREDITS [3-1-0]

Group: Structure of Groups, Isomorphism Theorems, Classification of groups of small order, Group Action, Sylow Theorems and their applications. Normal and Subnormal Series, Composition Series, Solvable Groups and Nilpotent Groups, Jordan-Hölder Theorem and its applications. [12]

Rings: Prime and Maximal Ideals, Quotient Field of an Integral Domain, Polynomial and Power Series Rings. Noetherian and Artinian Rings, Semisimple, Orders in simple Artinian rings, Hilbert Basis Theorem, Cohen's Theorem. [11]

Field Extensions: Normal Extension, Separable Extension, Impossibility of some constructions by straightedge and compass. Finite Fields and their properties, Galois Group of automorphisms and Galois Theory, Solution of polynomial equations by radicals, Insolvability of the general equation of degree 5(or more) by radicals. [12]

Modules: Basic definitions and examples, left and Right Modules over a ring with identity, Cyclic Modules, Free Modules, Fundamental Structure Theorem for finitely generated modules over a PID and its applications to finitely generated abelian groups. [10]

[Prerequisites: Modern Algebra (MA-2101))]

TEXT BOOKS:

1. **J.A. Gallian,** *Contemporary Abstract Algebra,* 4th ed., Narosa, 1999.
2. **Hungerford, T.W.,** *Algebra,* Springer.

REFERENCE BOOKS:

1. **Dummit, D.S., Foote, R.M.,** *Abstract Algebra*, Second Edition, John Wiley & Sons, Inc., 1999.
2. **Herstein, I.N.,** *Topics in Abstract Algebra*, Wiley Eastern Limited.
3. **Jacobson, N.,** *Basic Algebra, I & II*, Hindusthan Publishing Corporation, India.

MA 9116 Automata Theory and Algorithms 4 Credits [3-1-0]

Automata Theory:

Fundamentals: Methods of Proof, Basic Concepts of Languages, Definitions and classification of Grammers, Alphabet, Strings, Languages, Finite Representation of Languages. [5]

Finite Automata(FA): Deterministic Finite State Automata,Non-deterministic Finite State Automata, Regular Expressions, Regular Grammer, Ambiguity of Regular Languages, Pumping Lemma for regular language, Myhill-NerodeTheorem. [6]

Closure Properties of Regular Language: Closure under Boolean operations, reversal, homomorphism, inverse homomorphism, etc. Pumping lemma. [4]

Context Free Grammers (CFG): Pumping Lemma of Context Free Language (CFLs),

Closure properties of CFL: closure under union, concatenation, Kleene closure, substitution, homomorphism, reversal, intersection with regular set, Normal Forms, Derivation trees and ambiguity. [3]

Pushdown Automata: Pushdown Automaton, Equivalence between acceptance by Final State, Equivalence of Context Free Grammer and Pushdown Automaton.

Turing Machine (TM): Turing Machine as an Acceptor and as a Computing device, Techniques for Turing Machine construction, Equivalence between Turing Machine and Type 0 Language, The Halting problem.

Context-sensitive languages, Recursive and Recursive Enumerable sets, Chomsky Hierarchy. [5]

Algorithms:

Analysis of Algorithms: Analysis of Algorithms, Asymptotic notations-big ohm, omega and theta. Average case analysis of simple programs like finding of a maximum of n elements. Recursion and its systematic removal. [8]

Design of Algorithms: (Divide and Conquer, Greedy method, Dynamic programming, Back tracking, Branch and Bound). Lower bound theory, Non – deterministic algorithm – Non – deterministic programming constructs. Simple non-deterministic programs. NP – hard and NP – complete problems. [7]

Different types of Algorithms: Quicksort – Non – recursive implementation with minimal stack storage. Sorting and Searching Algorithms, Interpolation and Binary Search. [7]

TEXT BOOKS:

1. **Hopcroft, Ullman,** *"Introduction to Automata Theory, Languages and Computation",* Pearson Education.

2. **K.L.P. Mishra and N. Chandrasekaran,** *"Theory of Computer Science: Automata, Languages and Computation",* PHI Learning Private Limited, Delhi India.

REFERENCE BOOKS:

1. **Peter Linz,** *"An Introduction to Formal Language and Automata",* Narosa Publishing house.
2. **Papadimitrou, C. and Lewis, C.L.,** *"Elements of the Theory of Computation",* PHI Learning Private Limited,Delhi India.

MA 9117 DIFFERENTIAL GEOMETRY 4 CREDITS [3-1-0]

Vector Fields: height of the level set, level curves, Integral curve, smooth vector field, The tangent Space: tangent to the level set, gradient, Surfaces: Hyperplane, Lagrange multiplier, Vector Fields on Surfaces, maximal integral curve, orientation and its consistency, Osculating plane, Serret Frenet formula, Singular points and their classification Gauss, The Gauss map spherical image, one-sheeted hyperboloid. [16]

Geodesics: maximal geodesic, great circle, Parallel Transport, covariant derivative and acceleration, Fermi derivative, The Weingarten Map: shape operator, geodesic flow. [8]

Curvature of plane curves: center of curvature, radius of curvature, Isometries, Intrinsic differentiation, Gauss-Kronecker curvature, translation, rotation, Fundamental theorem on curves. [10]

Riemannian metrics: Hyperbolic metric, Stereographic projection, Poincare metric, affine and Riemannian connection and covariance derivation, Applications of differential geometry in engineering and sciences. [11]

TEXT BOOKS:

1. **J. A. Thorpe,** *Elementary Topics in Differential Geometry,* Springer (India), 2004.
2. **B. O'Neill,** *Elementary Differential Geo-metry,* Academic Press, New York, 1966.

REFERENCE BOOKS:

1. **M. DoCarmo,** *Differential Geometry of Curves and Surfaces*, Prentice Hall, 1976.
2. **J.J. Stoker,** *Differential Geometry, Wiley-Interscience,* 1969.

MA 9118 Optimization Techniques 4 CREDITS [3-1-0]

Non-linear programming: Lagrangian function, NLPP with equality constraint, NLPP with inequality constraint, Kuhn-Tucker conditions, Quadratic programming, Convex Programming, Separable Programming. [12]

Goal Programming: General goal programming models, Model with single goal, Model with multiple goals-equally ranked, Model with multiple goals-priority ranked, Graphical method of goal programming, Simplex method in goal programming. [8]

Stochastic Programming: Chance constrained programming technique, Stochastic linear programming, Stochastic non-linear programming, Two stage programming technique. [7]

Geometric Programming: Posynomial, Unconstrained GPP using differential Calculus, Unconstrained GPP using Arithmetic – Geometric Inequality, Constrained GPP. [8]

Unconstrained Optimization Techniques: Rate of convergence, Direct search method, Indirect search method. [10]

TEXT BOOKS:

1. **A. Ravindran, K. M. Ragsdell and G. V. Reklaitis**, *Engineering Optimization-Methods and Applications,* Wiley-India Edition.
2. **Singiresu S. Rao,** *Engineering Optimization -Theory and Practice,* New Age International (P) Limited.

REFERENCE BOOKS:

1. **R. Fletcher,** *Optimization,* Academic Press, 1969.
2. **D. G. Luenberger,** *Introduction to Linear and Nonlinear Programming,* AddisonWesley,1973.
3. **Z.S. Kambo**, *Mathematical Programming Techniques*, East West Press, 1997

MA 9119 FUZZY MATHEMATICS 4 credits [3-1-0]

Basic concepts of fuzzy sets and fuzzy logic, Motivation, Fuzzy sets and their representations, Membership functions and their designing, Operations on fuzzy sets, Convex fuzzy sets, Alpha-level cuts, Geometric interpretation of fuzzy sets. [10]
Fuzzy extension principle and its application. [2]
Fuzzy numbers, Fuzzy numbers in the set of integers, Arithmetic operations on fuzzy numbers. [6]

Linguistic variables, Linguistic modifiers, Fuzzy rules, Fuzzy relations, Basic properties of fuzzy relations, Composition of fuzzy relations, Fuzzy reasoning. [6]

Fuzzy mapping rules and fuzzy implication rules, Fuzzy rule-based models for function approximation, Types of fuzzy rule-based models (the Mamdani, TSK, and standard additive models), Fuzzy implications and approximate reasoning. [5]

Fuzzy logic, Truth, Propositions of fuzzy logic, Fuzzy logic and probability theory, Possibility and Necessity, Possibility versus probability, Probability of a fuzzy event, Baye's theorem for fuzzy events, Probabilistic interpretation of fuzzy sets. [6]

Decision making in Fuzzy environment, Fuzzy Multi criteria analysis, Multistage decision making, Decision making using Fuzzy ranking methods, Fuzzy Linear programming, Fuzzy goal programming, Fuzzy Multi-objective decision making. [10]

TEXT BOOKS:

1. H. J. Zimmermann, Fuzzy Set Theory and its Applications: Second Edition, Kluwer Academic Publishers, Boston, 1991.
2. K. H. Lee, First Course on Fuzzy Theory and Applications, Springer, 2005

REFERENCE BOOKS:

1. W, Pedrycz, Fuzzy sets Engineering, CRC Press, 1995
2. G. J. Klir and T. A. Folger, Fuzzy sets, Uncertainty and Information, Prentice Hall, Englewood Cliffs, 1988.
3. G. J. Klir, U. S. Clair and B. Yuan, Fuzzy Set Theory: Foundation and Application, Prentice Hall, 1997.
4. G. Bojadzieve and M. Bojadzieve, Fuzzy Sets, Fuzzy Logic Applications, World Scientific, 1995.

MA 9120 NONLINEAR ANALYSIS 4 CREDITS [3-1-0]

Fixed Point Theorems with Applications: Properties of linear and nonlinear operators, Banach contraction mapping theorem, Picard's theorem, and applications of contraction principle. [14]

Topological Methods: Brouwer fixed point theorem, Contractible sets, Schauder fixed point theorem; fixed point theorem for non-compact operators; classical solution to PDEs, functional setting; classical solution, applications of fixed point theorems. [21]

Degree theory and condensing operators with applications. [10]

[Prerequisites: MA 2103 Functional Analysis]

TEXT BOOKS:

1. **E. Zeilder,** *Nonlinear Functional Analysis and Its Applications, Vol. I (Fixed Point Theory),* Springer Verlag, Berlin, 1985.

REFERENCE BOOKS:

1. **M. Schechter,** *An Introduction to Nonlinear Analysis,* Cambridge University Press, 2004.
2. **Yeol Je Cho, Yu-Qing Chen**, *Topological degree Theory and Applications*, Chapman and Hall/CRC, 2006.

MA -9121 **Advanced Operations Research** **4 credits [3-1-0]**

Queuing Theory: Introduction of Basic Concepts in Stochastic Processes. Markov Chain and Markov Processes.

Introduction to waiting line models steady state behaviour of M/M/1 and M/M/C queueing systems, Erlangian Queueing Systems: $M/E_k/1$ and $E_k/M/1$. Bulk Queueing Systems. Basic idea of priority systems. Imbedded Markov chain models: M/G/l, G/M/l, M/D/C. [12]

Probabilistic Inventory Management: Single period inventory models, newspaper boy problemswith or without salvage value, Periodic and Continuous review models, Inventory management of items with deterioration, Inventory management of items with inflation. [8]

Replacement , Reliability & Maintenance: Replacement of items that deteriorate, Equipments that suddenly fail, chain of improving equipments, assuming (1)same life for each member in thechain and (2)increasing life, equal to that of deterioration only at infinity. Replacement of items that fail stochastically-individual and common preventive replacements, Renewal theory.

Basics of reliability. classes of life distributions based on notions of ageing, Reliability models of non-maintained & maintained systems, Availability theory and it's modelling for various configurations. [14]

Sequencing Analysis: Two machine and n jobs (no passing) problem and three machine and n jobs (no passing) problems: different routing, 2 jobs and m machines, n jobs and m machines, branch and bound algorithms. [6]

Simulation: Implementation of simulation modeling, Design of simulation models.

Generation of random deviates, the uniform distribution and its importance to simulation, Generation of random numbers (Properties of uniformly distributed numbers, Mid-square technique, Mid-product, technique, Fibonacci method).

Generating uniform random variates via a congruential method (Mixed method, Multiplicative

method, Quadratic congruential method), testing a random number generator (Frequency test, Gap test, Runs test, Poker test).

Inverse transform method, (Exponential distribution, Weibull distribution, Geometric distribution), Rejection Techniques (Beta distribution, Gamma distribution), Composition method (Poisson distribution, Erlang distribution, Binomial distribution), Approximation techniques, Special probability distributions (Chi-square distribution, Student's T-distribution, F-distribution). [6]

TEXT BOOKS:

1. **Prem Kumar Gupta & D. S. Hira,** *Operations Research*, S Chand publication
2. **N.D. Vohra**, *Quantitative techniques in management*, Mc Graw hill.

REFERENCE BOOKS:

1. **Ravindran, Phillips and Solberg,** *Operations Research – Principles & Practice*, John Wiley & Sons
2. **F. S. Hiller & G. J. Leiberman,** *Introduction to Operations Research.* McGraw hill.

MA9122 Algebraic Coding Theory 4 credits [3-1-0]

Source Coding: Introduction to Information Theory, Uncertainty and Information, Average Mutual Information and Entropy, Information Measures, Information Rate. [7]

Introduction to Coding Theory: Basic Assumptions, Correcting and Detecting Error Pattern, the Effects of Error Correction and Detection, Finding the Most Likely Codeword Transmitted. Some Basic Algebra, Weight and Distance, Maximum Likelihood Decoding (MLD), Reliability of MLD, Error-Detecting Codes, Error-Correcting Codes. [8]

Linear Codes: Linear Codes, Independence, Basis and Dimension, Matrices, Bases for $C = \langle S \rangle$ and $C^{\perp}$, Generating Matrices and Encoding, Parity-Check Matrices, Equivalent Codes, Distance of a Linear Code, Cosets, MLD for Linear Codes. [8]

Finite Fields: Finite Fields: the basic theory, Field Extension: a brief idea, Irreducible Polynomial and how to find irreducible polynomial, The number of irreducible polynomials, Introductoin of Vector Spaces, Minimal Polynomial, Automorphisms Group of $GF(p^m)$ and Bases of $GF(p^m)$ over $GF(p)$. [8]

Perfect and Related Codes: Some Bounds for Codes, Perfect Codes, Hamming Codes, Extended Codes, the Extended Golay Code, Decoding the Extended Golay Code, Reed-Muller Codes. [7]

Cyclic Linear Codes: Polynomials and Words, Introduction to Cyclic Codes, Polynomial Encoding and Decoding, Finding Cyclic Codes, Dual Cyclic Codes. [7]

TEXT BOOKS:

1. **S Ling, C Xing,** *Coding Theory: A first course*, Cambridge, 2004.
2. **F J Macwilliams, N J A Sloane,** *The Theory of Error Correcting Code*, North-Holland, 1977.

REFERENCE BOOKS:

1. **D R Hankerson, D G Hoffmann, D A Leonard, C C Lindner, K T Phelps, C A Rodger, J R Wall,** *Coding Theory and Cryptography*, CRC, 2006,
2. **S Roman,** *Coding and Information Theory*, New York: Springer-Verlag, 1992.

MA 9123 Dynamical Systems and Chaos Theory **4 credits [3-1-0]**

I**ntroduction:** Continuous dynamical systems and discrete dynamical systems. [2]

One dimensional systems: Existence and uniqueness, Bifurcations and Flow on the circle. [4]

Two dimensional systems: Linearization and stability, Liapunov functions. Nonlinear Oscillations: Limit cycles in two dimensions, Poincaré-Bendixson theorem, Linear stability of limit cycle, Floquet theory, Poincaré sections, circle-maps and mode-locking, Relaxation & Coupled oscillators, Perturbation methods. [15]

Introduction to Chaos: Lorenz equations, Liapunov exponents, Strange and chaotic attractors, fractal boundaries, Logistic map. [12]

Bifurcations: Saddle-node, transcritical, pitchfork, Hopf, homoclinic and heteroclinic connections. [6]

Routes to chaos: Period doubling, quasiperiodic and intermittency. [6]

TEXT BOOKS:

1. **S. H. Strogatz,** *Nonlinear Dynamics and Chaos*, Westview Press, 2000.
2. **K. T. Alligood, T. D. Sauer, and J. A. Yorke,** *Chaos: An Introduction to Dynamical Systems.* Springer, 1996.

REFERENCE BOOKS:

1. **D. W. Jordan, and P. Smith,** *Nonlinear Ordinary Differential Equations*, Oxford University Press, 1999.
2. **P. Glendinning,** *Stability, instability and chaos*, Cambridge University Press, 1994.
3. **E. Ott,** *Chaos in Dynamical Systems*, Cambridge University Press, 2002.

MA 9124 Financial Mathematics 4 Credits [3-1-0]

Basics about stock market, investment and securities, stock return, risk, option and futures. [6]

Weiner process and its properties, Markov property, Martingale property. [8]

Stochastic differential equations: Ito Calculus, one dimensional diffusion process, Multidimensional diffusion process, Poisson Process. [10]

Black Scholes model: arbitrage, option values, pay offs and strategies, put-call parity, Black Scholes equation, similarity solution and exact formulae for European options, American option, call and put options. [10]

Binomial Methods: option valuation, dividend paying stock, general formulation and implementation. [3]

Finite difference methods: explicit and implicit methods, stability and convergence, finite difference methods for Black-Scholes PDE. [6]

Monte Carlo Simulation: valuation by simulation [2]

TEXT BOOK:

1. **D.G. Luenberger,** *Investment science,* Oxford University Press.
2. **B. Oksendal,** *Stochastic Differential Equations,* Springer-Verlag.

REFERENCE BOOKS:

1. **Lishang Jiang,** *Mathematical modelling and methods of option pricing,* World Scientific.

MA 9125 Computational Fluid Dynamics 4 credits [2-0-2]

Fundamentals of numerical analysis, ordinary differential equations and partial differential equations related to fluid mechanics and heat transfer. [15]

Error control and stability considerations. Numerical solutions of few boundary value problems involving Navier-Stokes equation. [30]

[Pre-requisite: Fluid Dynamics (MA-3103)]

TEXT BOOK:

1. **J. C. Tannehil, D. A. Anderson, and R. H. Pletcher,** *Computational Fluid Mechanics and Heat Transfer,* Taylor & Francis, 1997.

REFERENCE BOOKS:

1. **H. Fereziger and M. Peric,** *Computational Methods for Fluid Dynamics,* 2001.
2. **J.D. Anderson, Jr.,** *Computational Fluid Dynamics: The Basic with Applications,* McGraw Hill, Inc., 1995.

MA-9126 Soft Computing 4 credits [3-1-0]

Introduction of Soft Computing, Concepts and applications. [4]
Biological and artificial neuron, Neural networks, Adaline, Perceptron, Madaline and BP (Back Propagation) neural networks, Adaptive feedforward multilayer networks, RBF and RCE neural networks, Topologic organized neural networks, competitive learning, Kohonen maps, Solving optimization problems using neural networks, Stochastic neural networks, Boltzmann machine. [15]
Fuzzy sets, fuzzy logic and fuzzy inference, fuzzy decision-making. [5]
Genetic algorithms, Probabilistic reasoning, Rough sets. [8]
Ant colony optimization and Particle swarm optimization. [6]
Hybrid approaches (neural networks, fuzzy logic, genetic algorithms and rough sets), Engineering optimization problem solving using genetic algorithm, Neural network approaches, fuzzy and rough approaches. [7]

TEXT BOOKS:

1. D. K. Pratihar, Soft Computing, Narosa, 2008.
2. D. E. Goldberg, Genetic Algorithms in Search, Optimization and Machine learning, Pearson Education, Inc. 1989.

REFERENCE BOOKS:

1. S.N. Sivanandam and S. N. Deepa, Principles of Soft Computing, Wiley, 2012.
2. M. Dorigo and T. Stutzle, Ant Colony Optimization, Prentice Hall India Pvt. Ltd, 2005.
3. E. Bonabeau, M. Dorigo and G. Theraulaz, Swarm Intelligence: From Natural to Artificial Systems, New York, Oxford University Press, 1999.

MA 9127 Reliability Theory 4 credit[3-1-0]

Definition of reliability and its measures, concept of failure. General provision of a reliability specification, Methods of achieving reliability, Broad functions of reliability. [3]

Bath tub curve, causes of early failure and methods to avoid them, failure distributions: exponential, Weibull, truncated normal, log normal, gamma, inverse Gaussian, their properties and uses.

[4]

Time dependent reliability of components and system- Failure rate versus time curve, modelling of failure rate, estimation of failure rates from empirical data, mean time to failure(MTTF), Reliability & hazard functions for different distribution, expected residual life, Series, parallel and r-out of n configurations; their block diagram. [6]

Problem of life testing, estimation of parameters and reliability using standard probability models using complete and censored (type I, II and III) samples, properties of these estimators. Probability plotting and graphical procedures for estimating the parameter and testing validity of model by some standard statistical tests. Life test acceptance sampling plans in exponential case. Sequential life test in exponential case, accelerated life test. [10]

Problem of optimal design of plan under Bayesian consideration, truncation of number of failure and cost model based on cost of sampling, testing and decision of acceptance and rejection, sign regular function and monotone plan, posterior risk and minimisation of expected regret.

[6]

Reliability based optimum design- Introduction, Formulation of optimization problem, solution techniques. [6]

Failure modes, event tree & fault tree analysis-system safety analysis, Failure modes & effects analysis, Event tree analysis, Fault tree analysis. Minimal cut sets. [10]

TEXT BOOKS:

1. **S.S. Rao**, *Reliability engineering*, Pearson Publication.
2. **Bazvosky, I., Prentice Hall,** *Reliability Theory and Practice,* New Jersey.

REFERENCE BOOKS:

1. **Gertsbakh, I.B.,** *Statistical Reliability Theory,* Marcel Dekker Inc.
2. **Sinha, S.K.,** *Reliability and Life Testing,* Wiley Eastern Limited.
3. **Polvko, A.M.,** *Fundamentals of Reliability Theory,* Academic press, New York.
4. **Barlow, R.E. and Proschan, F,** *Mathematical Theory of Reliability,* John Wiley, New York.

5. **Gnedenko, Yu, Belyayev K and Solovyev, A.D.,** *Mathematical Methods of Reliability Theory*, Academic Press, New York.

MA 9128 Multivariate Statistical Analysis

4 credit [3-1-0]

Multivariate Analysis: Basic concepts, Measurement scales, Measurement error and Multivariate Measurement, Classification of Multivariate Techniques, Types of Multivariate Techniques, Structured Approach to Multivariate Model building [2]

Examining Data for Multivariate Analysis: Bivariate Profiling, Multivariate Profiles, Missing Data, Outliers, Detecting and Handling Outliers, Testing the assumptions of Multivariate Analysis [2]

Multivariate Normal Distribution: Multivariate Normal Density & its properties**,** Sampling from a multivariate Normal Distribution and maximum Likelihood estimation, sampling distribution of mean & standard deviation, Detecting outliers ,Transformation to near Normality. [5]

Principal Component Analysis: Population Principal Components, Principal components for covariance matrices with special structures, Sample Variation by Principal Components, Large sample inferences, monitoring quality with Principal components. [10]

Factor analysis: What is Factor analysis, Objectives of Factor analysis, designing a Factor analysis, Assumptions in Factor analysis, Deriving factors and assessing overall fit, 3 process factor interpretations, Validation of Factor Analysis. [6]

Multiple Discriminant Analysis and Logistic Regression: What are Discriminant Analysis and Logistic Regression, Objectives of Discriminant Analysis, assumptions of Discriminant Analysis, estimation of the Discriminant Model and assessing overall fit, Logistic Regression: Regression with a binary dependent variable [10]

Cluster Analysis: What is cluster analysis, Objectives of cluster analysis, Assumptions of cluster analysis, deriving clusters and assessing overall fit, Interpretation of the clusters, hierarchical & non-hierarchical clustering techniques. [10]

Text Books:

1. **J.F.Hair, W.C.Black,B.J.Babin,R.E.Anderson, R.L.Tatham,** *Multivariate Data Analysis*, Pearson Education.
2. **R. A. Johnson, D. W. Wichern,** *Applied Multivariate Statistical Analysis*, Pearson Education.

Reference Books:

1. **W.Hardle,L.Simar,***Applied Multivariate Statistical Analysis*, Springer.
2. **T.W.Anderson**, *An introduction to multivariate statistical analysis*, Wiley student edition.

MA9129 Number Theory 4 credits [3-1-0]

Infinitude of primes, discussion of the Prime Number Theorem, infinitude of primes in specific arithmetic progressions, Dirichlet's theorem (without proof). [5]

Arithmetic functions, Mobius inversion formula. Structure of units modulo$n$, Euler's phi function. [5]

Congruences, theorems of Fermat and Euler, Wilson's theorem, linear congruences, quadratic residues, law of quadratic reciprocity. [6]

Binary quadratics forms, equivalence, reduction, Fermat's two square theorem, Lagrange's four square theorem. [5]

Continued fractions, rational approximations, Liouville's theorem, discussion of Roth's theorem, transcendental numbers, and transcendence of e and pi. [6]

Diophantine equations: Brahmagupta's equation (also known as Pell's equation), the Thue equation, Fermat's method of descent, discussion of the Mordell equation. [5]

Discussion of Waring's problem. [2]

Discussion of the Bhargava-Conway "fifteen theorem" for positive definite quadratic forms. [3]

The RSA algorithm and public key encryption. [3]

Primality testing, discussion of the Agrawal-Kayal-Saxenatheorem.Algebraic number fields. [5]

TEXT BOOKS:

1. **S. Lang,** *Algebraic Number Theory: Addison- Wesley*, 1970.
2. **Niven and H.S. Zuckerman,** *An Introduction to the Theory of Numbers*, 4th Ed., Wiley, New York, 1980.

REFERENCES BOOKS*:*

1. **W.W. Adams and L.J. Goldstein,** *Introduction to the Theory of Numbers,* 3rd ed., WileyEastern, 1972.
2. **Baker,** *A Concise Introduction to the Theory of Numbers*, Cambridge University Press, Cambridge, 1984.

MA9130 **Cryptology** **4 credits [3-1-0]**

Pre-requisites: Modern algebra.

Secure communications, shift ciphers, affine ciphers, vigenere cipher, symmetric key, public key, block ciphers (DES, AES), Shannon's Notion of perfect secrecy, one time pads, secure random bit generator, linear feedback shift register sequences, stream ciphers (LFSR based, RC4), Block cipher modes of operations. [15]

Differential cryptanalysis, Linear cryptanalysis. [7]

Prime number generation, RSA, attack on RSA, Diffie-Hellman key exchange, El Gamal public key cryptosystem, cryptographic hash function, RSA signature, El Gamal signatures, hashing and signing, digital signature algorithm. [8]

Elliptic Curves, Basic facts. Elliptic curve cryptasystems. [8]

One-way functions, PRG, PRP. [7]

TEXT BOOKS:

1. **J Hoffstein, J Pipher, J H Silverman,** An introduction to Mathematical Cryptography, 2e, Springer, 2014.
2. **D R Stinson,** *Cryptography: Theory and Practice.* CRC Press. 2006.

REFERENCE BOOKS:

1. **Johnnes A Buchmann,** *Introduction to Cryptography*, Springer, 2001.
2. **W Trappe and L C Washington,** *Introduction to Cryptography with coding Theory*, Prentice-Hall, 2006.
3. **Richard J. Spillman,** *Classical and Contemporary Cryptology*, Prentice Hall, 2005.

MA 9131 **Decision Theory** **4 CREDITS [3 -1 -0]**

Randomization, Optimality, Bayes rules, Minimax rules, Admissiable rules, Invariance and sufficiency, Complete class and essential complete class of rules. [8]

Decision analysis under Risk-Probability: Decision analysis without sampling, Decision analysis with sampling. [5]

Decision Analysis under Risk Utility: St. Petersburg Paradox. Construction of Utility Functions, Risk Attitudes. [5]

Decision Trees and Sequential Decision Making [4]

Multi-criteria decision methods [6]

Multi-objective optimization: Lexicographic optimality, Interactive procedures, efficient and properly efficient solutions. [6]

Data Envelopment Analysis: Chames, Cooper and Rhodes (CCR) model. Banker, Charnes and Cooper (BCC) model. [5]

Analytic Hierarchy Process: Ranking and weighting information using Eigen Vector Method (EVM) and Approximation Methods. [6]

TEXT BOOKS:

1. **Martin Peterson,** *An Introduction to Decision Theory,* Cambridge University Press. 2009.
2. **Itzhak Gilboa,** *Theory of Decision under Uncertainty,* Cambridge University Press. 2008.

REFERENCE BOOK:

1. **Giovanni Parmigiani, Lurdes Inoue,** *Decision Theory: Principles and Approaches,* Wiley, 2009.