DEPARTMENT OF MATHEMATICS

Scheme & Syllabus
M.Sc. (Mathematics)

W.E.F. 2017-18

CENTRAL UNIVERSITY OF HARYANA
JANT-PALI, MAHENDERGARH
HARYANA-123031
www.cuh.ac.in

Department of Mathematics

Central University of Haryana
Mahendergarh, Haryana-123031

Scheme and Syllabus of M.Sc. Mathematics
(CHOICE BASED CREDIT SYSTEM)

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Course Type

Core Course (C)
Generic Elective Course (GEC)
Discipline Centric Elective Course (DCEC)
Skill Enhancement Elective Course (SEEC)

Total Credit: 96, Semester-wise distribution of credits: 24+ 24 + 24 + 24

CORE COURSE (C)

S. No.	Course code	Course title	L	T	P	C
1.	SPMMAT 01 01 01 C 3104	Real Analysis	3	1	0	4
2.	SPMMAT 01 01 02 C 3104	Abstract Algebra	3	1	0	4
3.	SPMMAT 01 01 03 C 3104	Complex Analysis	3	1	0	4
4.	SPMMAT 01 01 04 C 3104	Differential Equations and Calculus of Variation	3	1	0	4
5.	SPMMAT 01 02 01 C 3104	Linear Algebra	3	1	0	4
6.	SPMMAT 01 02 02 C 3104	Topology	3	1	0	4
7.	SPMMAT 01 02 03 C 3104	Numerical Analysis	3	1	0	4
8.	SPMMAT 01 02 04 C 3104	Mathematical Statistics	3	1	0	4
9.	SPMMAT 01 03 01 C 3104	Integral Equations	3	1	0	4
10.	SPMMAT 01 03 02 C 3104	Functional Analysis	3	1	0	4
11.	SPMMAT 01 03 03 C 3104	Operations Research	3	1	0	4
12.	SPMMAT 01 03 04 C 3104	Number Theory	3	1	0	4
13.	SPMMAT 01 03 05 C 3104	Mechanics	3	1	0	4

DISCIPLINE CENTRIC ELECTIVE COURSES (DCEC)
(Offered to the students of M.Sc. Mathematics)

S. No.	Course code	Course title	L	T	P	Credit
1.	SPMMAT 01 02 01 DCEC 3104	Rings and Modules	3	1	0	4
2.	SPMMAT 01 02 02 DCEC 3104	Fluid Dynamics	3	1	0	4
3.	SPMMAT 01 02 03 DCEC 3104	Fuzzy Set Theory	3	1	0	4
4.	SPMMAT 01 02 04 DCEC 2124	Programming in MATLAB	2	1	2	4
5.	SPMMAT 01 03 01 DCEC 3104	Wavelet Analysis	3	1	0	4
6.	SPMMAT 01 03 02 DCEC 2124	Object Oriented Programming with C++	2	1	2	4
7.	SPMMAT 01 03 03 DCEC 3104	Information Theory	3	1	0	4
8.	SPMMAT 01 03 04 DCEC 3104	Applied Discrete Mathematics	3	1	0	4
9.	SPMMAT 01 03 05 DCEC 3104	Finite Element Analysis	3	1	0	4
10.	SPMMAT 01 04 01 DCEC 3104	Differential Geometry	3	1	0	4
11.	SPMMAT 01 04 02 DCEC 3104	Mathematical Modelling	3	1	0	4
12.	SPMMAT 01 04 03 DCEC 3104	Advanced Numerical Analysis	3	1	0	4
13.	SPMMAT 01 04 04 DCEC 3104	Theory of Elasticity	3	1	0	4
14.	SPMMAT 01 04 05 DCEC 3104	Advanced Complex Analysis	3	1	0	4
15.	SPMMAT 01 04 06 DCEC 3104	Cryptography	3	1	0	4
16.	SPMMAT 01 04 07 DCEC 3104	Advanced Abstract Algebra	3	1	0	4
17.	SPMMAT 01 04 08 DCEC 3104	Measure Theory and Integration	3	1	0	4

GENERIC ELECTIVE COURSE (GEC)
(Offered to PG students of other departments only)

S. No.	Course code	Course title	L	T	P	Credit
1.	SPMMAT 01 01 01 GEC 3104	Introduction to Mathematical Analysis	3	1	0	4
2.	SPMMAT 01 01 02 GEC 3104	Numerical Methods	3	1	0	4
3.	SPMMAT 01 01 03 GEC 2124	Programming in C	2	1	2	4
4.	SPMMAT 01 01 04 GEC 3104	Mathematics for Chemists	3	1	0	4

5.	SPMMAT 01 02 01 GEC 2124	Typesetting in LaTeX	2	1	2	4
6.	SPMMAT 01 02 02 GEC 2124	Numerical Programming in C	2	1	2	4
7.	SPMMAT 01 02 03 GEC 3104	Discrete Mathematics	3	1	0	4

Skill Enhancement Elective Course (Compulsory and exclusively for M.Sc. Mathematics students, non-credit, only qualifying in nature) this may include a course based on Theoretical/Experimental/Computational Techniques/Methods. The department may offer more than one courses depending on specialization and strength of faculty members, and the student has to opt one of them.

Semester I

Total credits: 24 (C: 20, GEC: 4)

S. No.	Course Title	Course Code	L	T	P	Credits
1	Real Analysis	SPMMAT 01 01 01 C 3104	3	1	0	4
2	Abstract Algebra	SPMMAT 01 01 02 C 3104	3	1	0	4
3	Complex Analysis	SPMMAT 01 01 03 C 3104	3	1	0	4
4	Differential Equations and Calculus of Variation	SPMMAT 01 01 04 C 3104	3	1	0	4
5	Seminar	SPMMAT 01 01 05 C 4004	4	0	0	4
6	GEC (to be taken from other departments)		-	-	-	4

The following GEC courses are offered to PG students of other departments only.

Introduction to Mathematical Analysis	SPMMAT 01 01 01 GEC 3104
Numerical Methods	SPMMAT 01 01 02 GEC 3104
Programming in C	SPMMAT 01 01 03 GEC 2124
Mathematics for Chemists	SPMMAT 01 01 04 GEC 3104

Semester II

Total credits: 24 (C: 16, DCEC: 4, GEC: 4)

S. No.	Course	Course Code	L	T	P	Credits
1	Linear Algebra	SPMMAT 01 02 01 C 3104	3	1	0	4

S. No.	Course	Course Code	L	T	P	Credits
2	Topology	SPMMAT 01 02 02 C 3104	3	1	0	4
3	Numerical Analysis	SPMMAT 01 02 03 C 3104	3	1	0	4
4	Mathematical Statistics	SPMMAT 01 02 04 C 3104	3	1	0	4
5	DCEC		-	-	-	4
6	GEC (to be taken from other departments)		-	-	-	4

DCEC (For students of M.Sc. (Mathematics) only)

Rings and Modules	SPMMAT 01 02 01 DCEC 3104
Fluid Dynamics	SPMMAT 01 02 02 DCEC 3104
Fuzzy Set Theory	SPMMAT 01 02 03 DCEC 3104
Programming in MATLAB	SPMMAT 01 02 04 DCEC 2124

GEC courses offered to PG students of other departments only

Typesetting in LaTeX	SPMMAT 01 02 01 GEC 2124
Numerical Programming in C	SPMMAT 01 02 02 GEC 2124
Discrete Mathematics	SPMMAT 01 02 03 GEC 3104

Semester III

Total credits: 24 (C: 20, DCEC: 4)

S. No.	Course	Course Code	L	T	P	Credits
1	Integral Equations	SPMMAT 01 03 01 C 3104	3	1	0	4
2	Functional Analysis	SPMMAT 01 03 02 C 3104	3	1	0	4
3	Operations Research	SPMMAT 01 03 03 C 3104	3	1	0	4
4	Number Theory	SPMMAT 01 03 04 C 3104	3	1	0	4
5	Mechanics	SPMMAT 01 03 05 C 3104	3	1	0	4
6	DCEC		-	-	-	4

DCEC courses for M.Sc. (Mathematics) students only

Wavelet Analysis	SPMMAT 01 03 01 DCEC 3104
Object Oriented Programming C++	SPMMAT 01 03 02 DCEC 2124
Information Theory	SPMMAT 01 03 03 DCEC 3104
Applied Discrete Mathematics	SPMMAT 01 03 04 DCEC 3104
Finite Element Methods	SPMMAT 01 03 05 DCEC 3104

Semester IV

Total credits: 24 (DCEC: 12, PROJ: 12)

S. No.	Course	Course Code	L	T	P	Credits
1	DCEC		3	1	0	4
2	DCEC		3	1	0	4
3	DCEC		3	1	0	4
4	Project/Dissertation	SPMMAT 01 04 01 PROJ	-	-	-	12
5	SEEC		-	-	-	0

DCEC courses for M.Sc. (Mathematics) students only

SPMMAT 01 04 01 DCEC 3104 Differential Geometry
SPMMAT 01 04 02 DCEC 3104 Mathematical Modelling
SPMMAT 01 04 03 DCEC 3104 Advanced Numerical Analysis
SPMMAT 01 04 04 DCEC 3104 Theory of Elasticity
SPMMAT 01 04 05 DCEC 3104 Advanced Complex Analysis
SPMMAT 01 04 06 DCEC 3104 Cryptography
SPMMAT 01 04 07 DCEC 3104 Advanced Abstract Algebra
SPMMAT 01 04 08 DCEC 3104 Measure Theory and Integration

OR

Total credits: 24 (PROJ: 24)*

S. No.	Course	Course Code	L	T	P	Credits
1	Project/Dissertation	SPMMAT 01 04 02 PROJ	-	-	-	24

***On Departmental Committee Recommendation**

SEEC (Skill Enhancement Elective Course**,** non-credit, only qualifying in nature): This may include a course based on Theoretical/Experimental/Computational Techniques/Methods. The department may offer more than one courses depending on specialization and strength of faculty members, and the student has to opt one of them. The course code may be given as: SPMMAT 01 04 0X SEEC 3100, X=1, 2, 3 ... etc.

SEMESTER - I

REAL ANALYSIS

(SPMMAT 01 01 01 C 3104)

UNIT - I

Metric Space and examples, open sets, closed sets, neighbourhood, unitary space, Euclidean space, Sequences in Metric spaces and convergence.

UNIT- II

Cauchy sequences, complete metric spaces and examples, Baire's theorem, Continuity, spaces of continuous functions, monotonic functions.

UNIT - III

Compactness, sequential compactness, functions continuous on compact sets, Bolzano-Weierstrass property, connectedness, components, Uniform continuity, totally disconnected.

UNIT- IV

Functions of Bounded variation, Total variations, functions of bounded variations expressed as difference of increasing functions, continuous function of bounded variations, Riemann and Riemann-Stieltjes integral.

Suggested Readings:

1. Simmons, G. F. *Introduction to Topology and Modern Analysis*. McGraw-Hill Pvt. Ltd. 2016.
2. Apostol, T. M. *Mathematical Analysis*. Fifth edition. *Wesley Publishing Co.* 1981.
3. Kumaresan, S. *Topology of Metric Spaces*. Narosa Publishing House, 2011.
4. Walter, R. *Principles of Mathematical Analysis*. 3rd edition, McGraw-Hill, 1976.
5. Malik, S. C. and Arora, S. *Mathematical Analysis*. Second edition reprint. New Age International Publishers 2005.
6. Royden, H. L. *Real Analysis*, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.
7. Somasundram, D. and Chaudhary, B. *A First Course in Mathematical Analysis*. Narosa Publishing House, 1996.
8. Terence T. *Analysis II*. Hindustan Book Agency, 2009.

ABSTRACT ALGEBRA

(SPMMAT 01 01 02 C 3104)

UNIT - I

Review of group theory, the class equation, Cauchy`s theorem, Sylow p-subgroups and its applications, Direct product of groups, description of group of order p^2 and pq, where p and q are distinct primes(In general survey of groups upto order 15).

UNIT - II

Zassenhaus lemma, Normal and subnormal series, Composition series, Jordan-Holder theorem, Solvable series, Derived series, Solvable groups, Solvability of S_n – the symmetric group of degree $n \geq 2$ Structure theorem for finitely generated abelian groups.

UNIT – III

Extension fields. Finite, algebraic, and transcendental extensions. Splitting fields. Simple and normal extensions. Perfect fields. Primitive elements. Algebraically closed fields.

UNIT – IV

Automorphisms of extensions. Galois extensions. Fundamental theorem of Galois Theory. Galois group over the rationals.

Suggested Readings:

1. Gallian, J. *A. Contemporary Abstract Algebra*. 9th edition. Cengage Learning, 2015.
2. Herstein, I. N. *Topics in Algebra*. 2nd edition. John Wiley and Sons, 2006.
3. Khanna, V. K. and Bhammbri, S. K. *A Course in Abstract Algebra*. Vikas Publishing house, 1999.
4. Bhattacharya, P. B. Jain, S. K. and Nagpaul, S. R. *Basic Abstract Algebra.* 2nd edition, Cambridge University Press, 2003.
5. Lang, S. *Algebra*. 3rd edition, Springer 2012.
6. Luther, S. and Passi, I. B. S. *Algebra*. Vol. I-Groups, Vol. II-Rings, Narosa Publishing House (Vol. I – 1996, Vol. II –1990).
7. Cohn, P. M. *Algebra.* Vols. I & II, John Wiley & Sons, 1991.

COMPLEX ANALYSIS
(SPMMAT 01 01 03 C 3104)

UNIT-I

Continuity, Differentiability, Cauchy-Riemann equations, Harmonic Functions, Analytic functions, Analytic functions as mapping. The Exponential function, Trigonometric functions, Logarithmic functions, Branch point, Branch cut.

UNIT-II

Power series representation of analytic functions, zeros of analytic functions, the index of a closed curve, Cauchy's theorem and integral formula, Homotopic version of Cauchy's theorem and simple connectivity. Counting zeros, Rouche's Theorem, Liouville's Theorem, the open mapping theorem, Goursat theorem, Morera's Theorem.

UNIT-III

Taylor's series, Laurent's series, Classification of singularities, residues, argument principle and their applications. Contour integrals

UNIT-IV

Maximum modulus theorem, Schwarz's lemma and their applications. Mobius transformations, Conformal mapping.

Suggested Readings:

1. Conway, J. B. Functions of One Complex Variable, Springer, 2012.
2. Brown, J. B. and Churchill, R. V. *Complex Variables and Applications*. 8th edition, Tata McGraw-Hill Education, 2009.
3. Mathews, John H. and Howell, Russell W. *Complex Analysis for Mathematics and Engineering*. Jones & Bartlett Publishers, 2012.
4. Copson, E. T. *Theory of Functions of Complex Variables*. Oxford University Press, 1970.
5. Saff, E. B. and Snider, A. D. *Fundamentals of Complex Analysis with Applications to Engineering and Sciences*. Pearson Education, 2014.
6. Ponnusamy, S. *Foundations of Complex Analysis*. Alpha Science International, 2005.

DIFFERENTIAL EQUATIONS AND CALCULUS OF VARIATIONS

(SPMMAT 01 01 04 C 3104)

UNIT-I

Preliminaries of ODE, PDE, Existence and Uniqueness theorem, Existence of independent solutions, Wronskian, Abel's formula, trajectories, orthogonality of functions, orthonormal set of functions, Sturm Liouville's boundary value problems, General properties of solution of linear differential equation of order n.

UNIT-II

Fourier Transform, Fourier sine and cosine transforms, Applications of Fourier Transform for solving differential equations. Regular and singular points, Power series solution of differential equation at regular and irregular singular points, Bessel's and Legendre's equations and their solutions.

UNIT-III

Classification of PDEs, Introduction to Lagrange's method, Charpit's method and Jacobi method. Solution of Laplace, Wave and diffusion equations by method of separation of variables in Cartesian coordinates.

UNIT-IV

Extrema of Functionals: Euler's equation, sufficient conditions for the Extremum of a Functional, Extension of the variational methods, Brachistochrone problem, Geodesics.

Suggested Readings:

1. Simmons, G. F. *Differential Equations with Applications and Historical Notes.* 2nd edition, Tata McGraw Hill, New Delhi, 2016.
2. Gelfand, I. M. and Fomin, S. V. *Calculus of Variations*. Courier Corporation, 2012.
3. Lebedev, N. N. *Special Functions and Their Applications. Revised*, Courier Corporation, 2012.
4. Bell, W. W. *Special Functions for Scientists and Engineers*. Courier Corporation, 2004.
5. Reid, W. T. *Ordinary Differential Equations.* John Wiley and Sons, New York, 1971.
6. Raisinghania, M. D. *Advanced Differential Equations*. S. Chand & Company Ltd., New Delhi, 2001.
7. Ross, S. L. *Differential Equations.* 3rd edition, Wiley India, 2007.

GEC COURSES OFFERED TO PG STUDENTS OF OTHER DEPARTMENTS

INTRODUCTION TO MATHEMATICAL ANALYSIS

(SPMMAT 01 01 01 GEC 3104)

UNIT-I

Sets, different kinds of sets, infinite and finite sets, countability. Types of relations – void, universal, reflexive, symmetric, transitive and equivalence classes. Complex numbers, graphic representation and properties, polar form of complex numbers, de Movier's theorem.

UNIT-I

Functions, domain, co-domain, range, classification of real functions, algebraic and transcendental functions, even and odd functions, periodic functions, graphs of some important functions.

UNIT-III

Definition of sequence and its convergence, series and convergence. Quadratic equations and roots, nature of roots.

UNIT-IV

Limits, continuity and differentiability: Limit of a function, fundamental theorem on limits, methods of evaluating limits, existence of limit, left hand and right hand limit, continuity at a point, continuity in an interval, Differentiability of a function at a point and in an interval, Geometrical interpretation.

Suggested Readings:

1. Malik, S. C. and Arora, S. *Mathematical Analysis*. 2nd edition. New Age International Publishers 2005.
2. Walter, R. *Principles of Mathematical Analysis*. 3rd edition, McGraw-Hill, 1976.
3. Royden, H. L. *Real Analysis,* Macmillan Pub. Co., Inc. 4th Edition, New York, 1993.
4. Somasundram, D. and Chaudhary, B. *A First Course in Mathematical Analysis*. Narosa Publishing House, 1996.
5. Ram, B. *Discrete Mathematics*. Pearson Education, 2012.

NUMERICAL METHODS

(SPMMAT 01 01 02 GEC 3104)

UNIT-I

Errors in approximation, Absolute, Relative and percentage errors. Solution of algebraic and transcendental equations: Bisection method, Newton Raphson method, Systems of simultaneous Equations: Crammer's rule, Inversion method, Gauss elimination method, Gauss Jordon method, LU decomposition method, Iterative methods: Jacobi method and Gauss-Seidel method.

UNIT-II

Eigen values and Eigen vectors: Eigen values, Eigen vectors, Cayley Hamilton theorem, Power method for finding largest Eigen value. Curve fitting: Least square curve fit- Straight line fitting, parabolic curve fitting, fitting of exponential curve, fitting of other curves.

UNIT-III

Finite Differences: Forward difference, Backward difference, Central difference, Newton's forward, backward interpolation formulae, Lagrangian interpolation formula, Gauss forward, backward formulae, Stirling formula, Bessel formula.

UNIT-IV

Numerical Differentiation and Integration: Newton's forward difference, Newton's backward difference Formula for differentiation, Trapezoidal and Simpson's one third rules, Simpson's three eight rule for numerical integration, Double integrals using trapezoidal and Simpsons's rules.

Suggested Readings:

1. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. *Numerical Methods for Scientific & Engg. Computation*. New Age International, 2012.
2. Atkinson, K. E. *An Introduction to Numerical Analysis*. John Wiley & Sons, 1989.
3. Conte, S. D. and Boor, C. D. *Elementary Numerical Analysis*. An Algorithmic Approach, Tata McGraw Hill, New Delhi, 1981.
4. Isacson, E. and Keller, H. B. *Analysis of Numerical Methods*. John Wiley & Sons, 1994.
5. Thangaraj, P. *Computer Oriented Numerical Methods*. PHI Learning Pvt. Ltd, 2013.

PROGRAMMING IN C
(SPMMAT 01 01 03 GEC 2124)

Unit-I

An overview of programming, Programming languages, Classification, C Essentials Program Development, Anatomy of a C Function. Variables, Constants, Expressions, Assignment Statements, Formatting Source files, Continuation character, The Preprocessor. Scalar Data Types-Declarations, Different Types of Integers, Different kinds of integer constants, Floating point types, Initialization, Mixing types, Explicit conversions-casts. Data Types.

Unit-II

Operators and expressions - Precedence and Associatively. Unary Plus and Minus operators. Binary Arithmetic Operators. Arithmetic Assignment Operators. Increment and Decrement Operators. Comma Operator. Relational Operators. Logical Operators. Bit Manipulation Operators. Bitwise Assignment Operators. Cast Operator. Size of Operators. Conditional Operator. Memory Operators, Input/Output functions..

Unit-III

Control Flow - Conditional Branching, The Switch Statement. Looping. Nested Loops, The break and continue Statements. The goto statement. Infinite loops. Arrays - Declaring an array, Arrays and Memory. Initializing arrays, Encryption and Decryption. Multidimensional arrays, Strings.

Unit-IV

Functions - Passing Arguments, declarations and calls. Recursion, The main ( ) Function, Passing Arrays as Function Arguments. Pointers - Pointer Arithmetic, Accessing Array Elements through pointers, Passing Pointers as Function arguments, Arrays of pointers.

Suggested Readings:

1. Balagurusamy, E. *Programming in ANSI C*. Third edition. TATA McGraw Hill, 2016.
2. Darnell, P. A. and Margolis, P. E. *C: A Software Engineering Approach*. Narosa Publishing, House (Springer International Student Edition), 2012.
3. Yashavant, P. K. *Let Us C*. BPB Publication, 2008.
4. Byrons, G. *Programming With C*. 2nd edition, Schaum's Series, 1996.
5. Brain W. K. and Ritchie D. M. *The C Programme Language*. 2nd edition, ANSI features Prentice Hall 1989.

MATHEMATICS FOR CHEMISTS

(SPMMAT 01 01 04 GEC 3104)

UNIT-I

Algebraic, Transcendental functions, approximation, errors in approximation: Absolute, Relative and percentage errors. Matrices and their properties, some special matrices, matrix algebra, the inverse matrix, linear transformations, orthogonal matrices and orthogonal transformations.

UNIT-II

Solution of differential equations: First-order linear equations- Separable equations, homogeneous linear equations, Non homogeneous linear equations, Second-order differential equations with Constant coefficients: general solution, particular solution, linear equations in chemical kinetics, harmonic oscillator and some other applications.

UNIT-III

Singular points, Power series solution of differential equation at regular and irregular singular points, Bessel's and Legendre's equations and their solutions, Partial differentiation, Types of partial differential equations.

Line integrals, double integrals, change of variables, polar coordinates, volume integrals, Laplacian operator, finite difference operators.

UNIT-IV

Descriptive statistics: Measures of central tendency, measures of dispersion, Frequency and probability, Combinations of probabilities, Permutations and combinations, Binomial distribution, Gaussian distribution.

Suggested Readings:

1. Steiner, E. *The Chemistry Maths Book.* 2nd edition, Oxford University Press, 2008.
2. Raisinghania, M. D. *Advanced Differential Equations*. S. Chand & Company Ltd. New Delhi, 2001.
3. Gupta, S. C. and Kapoor, V. K. *Fundamentals of Mathematical Statistics.* S. Chand & Sons, 2014.
4. Lipschutz, S. and Lipson, M. *Linear Algebra*. 3rd edition, Tata McGraw-Hill, 2005.

SEMESTER – II

LINEAR ALGEBRA

(SPMMAT 01 02 01 C 3104)

UNIT-I

Vector Spaces: Definition and Examples, Subspaces, Linear dependence, Basis and Dimension, Sum and Direct Sum, Quotient spaces, Linear Transformations: Kernel and Image of a Linear Transformation, Rank and Nullity of a Linear Transformation, Matrix Mappings.

UNIT-II

Linear Mappings and matrices: Matrix representation of Linear Transformation, Change of Basis, Similarity. Polynomial of matrices, Characteristic polynomial, Cayley Hamilton Theorem, diagonalization, minimal polynomial, companion matrix.

UNIT-III

Canonical and Bilinear Forms: Triangular form, invariance, Primary decomposition, Jordon canonical form, Rational canonical Form, Bilinear and Quadratic forms.

UNIT-IV

Inner Product Space, examples and properties, Norms and Distances, Orthonormal basis, The Gram-Schmidt Orthogonalization, Orthogonal complements. The Adjoint of a Linear operator on an inner product space, Normal and self-Adjoint Operators, Unitary Operators.

Suggested Books:

1. Lipschutz, S. and Lipson, M. *Linear Algebra*. 3rd edition, Tata McGraw-Hill, 2005.
2. Lang, S. *Linear Algebra*. 3rd edition, Springer-Verlag, NewYork, 2013.
3. Hoffman, K. and Kunze, R. *Linear Algebra*. 2nd edition, Prentice Hall, 1971.
4. Axler, S. *Linear Algebra Done Right*. 2nd edition, Springer-Verlag, 2014.

TOPOLOGY

(SPMMAT 01 02 02 C 3104)

UNIT – I

Definition and examples of topological spaces, basis and sub-basis, Open sets, Closed sets. Interior points, Closure points. Limit points, Boundary points, exterior points of a set, Closure of a set, Derived set, Hausdorff spaces.

UNIT – II

Subspace topology, Continuous functions, convergence of sequences, sequential continuity, open and closed mappings, Homeomorphism, pasting lemma, Product topology. Tychonoff theorem.

UNIT – III

Connectedness, Continuity and connectedness, Connected subsets of the real line, components, path connectedness, locally connected, locally path connected. Compactness and its characterizations, Compact subspace of the real line, Continuity and compact sets, Compactness and finite intersection property

UNIT – IV

Countability and Separation axioms, T0, T1, T2, Lindelof spaces, Regular and Normal Spaces, Urysohn Lemma, Metrization Theorems (Urysohn Metrization, Nagata-Smirnov Metrization Theorem), Tietze Extension Theorem, Compactification.

Suggested Readings:

1. Munkres, J. R. *Toplogy*. Pearson Education, 2017.
2. Simmons, G. F. *Introduction to Topology and Modern Analysis*. Tata McGraw-Hill Education, 2016.
3. Joshi, K. D. *Introduction to General Topology*. Wiley Eastern Ltd, 1983.
4. Kelley, J. L. *General Topology*. 2nd edition, Springer, New York, 1991.
5. Pervin, W. J. *Foundations of General Topology*. Academic Press, 2014.
6. Singh, T. B. *Elements of Topology*. CRC Press, Taylor Francis, 2013.

NUMERICAL ANALYSIS

(SPMMAT 01 02 03 C 3104)

UNIT-I

Errors in approximation, Absolute, Relative and percentage errors. Solution of algebraic and transcendental equations: Bisection method, Regula Falsi method, Newton Raphson method. Systems of simultaneous Equations: Gauss elimination method, Gauss Jordon method, LU decomposition method, Iterative methods: Jacobi method and Gauss-Seidel method. Curve fitting: Straight line fitting, parabolic curve fitting, fitting of exponential curve, fitting of other curves.

UNIT-II

Finite Differences, Interpolation techniques: Interpolation with equal intervals-Newton Forward, Newton Backward, Gauss forward, Gauss Backward, Stirling, Bessel formulae. Interpolation with unequal intervals-Newton's divided difference, Lagrange interpolation technique. Numerical Differentiation using Newton Forward, Newton Backward formulae.

UNIT-III

Numerical Integration: Newton-Cotes Formulas, Trapezoidal rule, Simpson rule, Romberg's integration, Gauss-Legendre, Gauss-Chebychev formulas.

Solution of Ordinary differential equations: Single step methods: Taylor series method, Picard's method, Euler method, Euler modified method, Runge – Kutta methods, Multistep methods: Milne's and Adam's predictor and corrector methods

UNIT-IV

Classification of PDEs. Solution of partial differential equations by finite difference method. Solution of Laplace equation: standard and diagonal five point formula for solving Laplace and Poisson equations, Solution of One dimensional Heat equation: Schmidt method, Crank-Nicolson method, Solution of wave equation.

Suggested Readings:

1. Mathews, J. H. *Numerical Methods for Mathematics, Science and Engineering*. Prentice-Hall International Editions, 1992.
2. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. Numerical Methods for Scientific & Engg. Computation. New Age International, 2012.
3. Thangaraj, P. *Computer Oriented Numerical Methods*. PHI Learning Pvt. Ltd, 2013.
4. Chapra, S. C. and Canale, R. P. *Numerical Methods for Engineers*. McGraw Hill International Edition, 1998.
5. Bartels, R. H. Bealty, J. C. and Beatty, J. C. *An Introduction to Spline for use in Computer Graphics and Geometric Modeling*. Morgan Kaufmann Publisher, 2006.
6. Boor, C. D. *A Practical Guide to Splines*. Springer Verlag, 2001.

MATHEMATICAL STATISTICS

(SPMMAT 01 02 04 C 3104)

UNIT - I

Measures of central tendency and dispersion, moments, Measures of skewness and kurtosis, Correlation and regression. Axiomatic approach to the theory of probability, Sample space, additive and multiplicative law of probability, conditional probability. Definition and properties of random variables, discrete and continuous random variables, probability mass and density functions, distribution function. Concepts of bivariate random variables.

UNIT - II

Mathematical Expectation: Definition and its properties. Variance, Covariance, Moment generating function- definitions and their properties. Discrete distributions: Binomial, Poisson and geometric distributions with their properties.

UNIT - III

Continuous distributions: Uniform, Exponential, Gamma and Normal distributions with their properties, Central Limit Theorem (Only statement).

UNIT – IV

Statistical estimation, Testing of Hypothesis: Null and alternative hypotheses, Simple and composite hypotheses, Two types of errors, t, F and Chi-Square as sampling distribution and applications.

Suggested Readings:

1. Gupta, S. C. and Kapoor, V. K. *Fundamentals of Mathematical Statistics.* Sultan Chand & Sons, 2014.
2. Mood, A. M., Graybill, F. A. and Boes, D. C. *Introduction to the theory of Statistics*, Tata McGraw Hill, 2014.
3. Meyer, P. L. *Introductory Probability and Statistical Applications*. Addison-Wesley Publishing Company, 1970.
4. Baisnab, A. P. and Jas, M. *Element of Probability and Statistics*, Tata McGraw Hill, 1993.
5. Spiegel, M. R., Schiller, J. J. and Srinivasan, R. A. Probability and Statistics. Tata McGraw-Hill, 2014.

DCEC COURSES OFFRED TO M.SC. (MATHEMATICS) STUDENTS ONLY

RINGS AND MODULES

(SPMMAT 01 02 01 DCEC 3104)

UNIT-I

Rings, Examples (including polynomial rings, formal power series rings, matrix rings and group rings, integral domains, division rings , fields), ideals, prime and maximal ideals, rings of fractions, Chinese Remainder Theorem for pairwise comaximal ideals. Homomorphisms and isomorphisms of rings.

UNIT-II

Factorization in domains, Euclidean Domains, Principal Ideal Domains and Unique Factorizations Domains. Polynomial rings over UFD', Polynomial rings over field, Irreducibility Criteria

UNIT-III

Vector Spaces, Modules, Direct Products and Direct Sums, Quotients and monomorphisms of modules, Modules over PIDs and applications, Various Canonical Forms,

UNIT-IV

Simple and semisimple modules, Semisimple rings, Wedderburn-Artin structure Theory.

Suggested Readings:

1. Herstein, I. N. *Topics in Algebra*. Wiley Eastern Ltd., New Delhi, 2006.
2. Bhattacharya, P. B. Jain, S. K. and Nagpaul, S. R. *Basic Abstract Algebra, 2nd edition.* Cambridge University Press, 1997.
3. Cohn, P. M. *Algebra*. John Wiley & Sons, Vols. I: 1982, Vols. II: 1989, Vols. III: 1991.
4. Anderson, F. W. and Fuller, K. R. *Rings and Categories of Modules*. Springer-Verlag New York, 1992.
5. Dummit, D.S. and Foote, R.M. *Abstract Algebra (3rd revised edition).* Wiley, 2003.
6. Lang, S. *Algebra*. Springer, 2012.

FLUID DYNAMICS

(SPMMAT 01 02 02 DCEC 3104)

UNIT I.

Concept of fluids, Physical Properties of fluids, Continuum Hypothesis, density, specific weight, specific volume, Kinematics of Fluids: Eulerian and Lagrangian methods of description of flows, Equivalence of Eulerian and Lagrangian method, General motion of fluid element, integrability and compatibility conditions, strain rate tensor, streamline, path line, streak lines, stream function¸ vortex lines, circulation,

UNIT II

Stresses in Fluids: Stress tensor, symmetry of stress tensor, transformation of stress components from one co-ordinate system to another, principle axes and principle values of stress tensor Conservation Laws : Equation of conservation of mass (continuity equation), equation of conservation of momentum, Navier Stokes equation, Euler's equation of motion, equation of moments of momentum, Equation of energy.

UNIT III

Irrotational and Rotational Flows : Bernoulli's equation, Bernoulli's equation for irrotational flows, Two dimensional irrotational incompressible flows, Circle theorem, sources and sinks, sources sinks and doublets in two dimensional flows, methods of images.

UNIT IV

Approximate (analytical) solutions of Navier Stoke Equation, Order of magnitude analysis, Use of similarity variables in analytical solution techniques, Solutions of some benchmark problems like; Couette Flow, Axi-symmetric Flows, Creeping flows.

Suggested Readings:

1. O'Neil, M. E., and Chorlton, F. *Ideal and Incompressible Fluid Dynamics*. John Wiley & Sons, 1986.
2. Kundu, P.K., Cohen, I.M. and Dowling, R. David. *Fluid Mechanics*, 6th edition, Academic Press, 2015.
3. Yuan, S.W. *Foundations of Fluid Mechanics*. Prentice Hall of India Private Limited, New Delhi, 1976.
4. Besaint, W.H. and Ramsey, A.S. *A Treatise on Hydromechanics, Part II*. CBS Publishers, Delhi, 1988.
5. Curle, N. & Davies, H. J. *Modern Fluid Dynamics*. Vol 1, D Van Nostrand Company Ltd, London, 1968.

FUZZY SET THEORY

(SPMMAT 01 02 03 DCEC 3104)

UNIT-I

Concepts of Fuzzy Set, Standard Operations of Fuzzy Set, Fuzzy Complement, Fuzzy Union, Fuzzy Intersection, Other Operations in Fuzzy Set, T- norms and T- conorms. Interval, Fuzzy Number, Operation of Interval, Operation of - cut Interval, Examples of Fuzzy Number Operation.

UNIT-II

Definition of Triangular Fuzzy Number, Operation of Triangular Fuzzy Number, Operation of General Fuzzy Numbers. Approximation of Triangular Fuzzy Number, Operations of Trapezoidal Fuzzy Number, Bell Shape Fuzzy Number. Function with Fuzzy Constraint, Propagation of Fuzziness by Crisp Function, Fuzzifying Function of Crisp Variable, Maximizing and Minimizing Set, Maximum Value of Crisp Function.

UNIT-III

Integration and Differentiation of Fuzzy Function Product Set, Definition of Relation, Characteristics of Relation, Representation Methods of Relations, Operations on Relations, Path and Connectivity in Graph, Fundamental Properties, Equivalence Relation, Compatibility Relation, Pre-order Relation, Order Relation, Definition and Examples of Fuzzy Relation, Fuzzy Matrix, Operations on Fuzzy Relation.

UNIT-IV

Composition of Fuzzy Relation, - cut of Fuzzy Relation, Projection and Cylindrical Extension, Extension by Relation, Extension Principle, Extension by Fuzzy Relation, Fuzzy distance between Fuzzy Sets. Graph and Fuzzy Graph, Fuzzy Graph and Fuzzy Relation, - cut of Fuzzy Graph.

Suggested Readings:

1. Lee, K. H. *First Course on Fuzzy Theory and Applications*. Springer International Edition, 2005.
2. Mohan, C. *An Introduction to Fuzzy Set Theory and Fuzzy Logic.* Anshan Publishers, 2009.
3. Zimmerman, H. J. *Fuzzy Set Theory and its Applications*. Allied Publishers Ltd., New Delhi, 1991.
4. Yen, J., Langari, R. *Fuzzy Logic - Intelligence, Control and Information*. Pearson Education, 1999.

PROGRAMMING IN MATLAB

(SPMMAT 01 02 04 DCEC 2124)

Unit-I

Overview of MATLAB, operators, Display format, elementary built-in functions, working with variables, General commands, data types, data import, arrays, operations with arrays.

Unit-II

Matrices: Eigenvalues and Eigenvectors, Similarity Transformation and Diagonalization, Functions, Script files, operators, Loops and Conditional Statements, Programming in MATLAB, Graphics- 2-D and 3-D Plots, input and output.

Unit-III

Applications in Numerical Methods: System of linear equations, L U Decomposition, Gauss elimination method, Gauss Seidel Method, Gauss Jordan Method. Interpolation: Lagrange and Newton Polynomials, curve fitting, Bisection Method, False Position (Regula-Falsi) Method, Newton–Raphson) Method

Unit-IV

Applications to Numerical differentiation and integrations: Trapezoidal Method and Simpson Method, Runge–Kutta Method, Introduction to working with modules in MATLAB.

Suggested Readings:

1. Otto, S.R. and Denier, J.P. *An Introduction to Programming and Numerical Methods in MATLAB*. Springer-Verlag, 2005.
2. Pratap, R. *Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers*. Oxford University Press, 2016.
3. Yang, W. Y., Cao, W., Chung, T. and Morris, J. *Applied Numerical Methods using MATLAB*. John Wiley Interscience, 2005.
4. Kumar, S. S. and Lenina, S. V. B. *Matlab: Easy Way of Learning*. PHI Learning Pvt. Ltd., 2016.
5. *Getting Started with MATLAB*, Maths Works Inc. *www. in.mathsworks.com.*

GEC COURSES OFFRED TO PG STUDENTS OF OTHER DEPARTMENTS

TYPESETTING IN LATEX

(SPMMAT 01 02 01 GEC 2124)

UNIT I

Preparing an input file, sentences and paragraphs, the document class, sectioning, display material, running LaTeX, changing the type style, producing mathematical symbols and mathematical formulae, arrays, delimiters, multiline formulae, putting one thing on other, spacing in math mode.

UNIT II

Defining command and environments, Producing and including graphics in a LaTeX file, figures and other floating bodies, lining it up in columns, table of content, cross-reference, bibliography and citation, making index and glossary, slides, overlays and notes, letters.

UNIT III

Design it yourself: document class, page style, title page, customizing the style, line and page breaking, numbering, length, spaces and boxes, formatting with boxes, centring and flushing, list making environments, changing font type size and special symbols, picture, picture environments, picture objects, text, boxes, straight lines, arrow, stacks, circles, oval, framing, curve, grid, repeat patterns.

UNIT IV

Making presentation slides in beamer class LaTeX, various styles in beamer presentation, dynamic slides. PostScript macros for Generic TeX (PsTrix): arguments, dimension, coordinates, angles, line styles, fill styles, custom styles, custom graphics, picture tools, text tricks, node and connection special tricks. Basics of MathJax, MathJax configuration options.

Suggested Readings:

1. Leslie Lamport. *A Document Preparation System User's Guide and Reference Manual*, Addison-Wesley Publishing Company, 2001.
2. Kottwitz, S. *LaTeX Beginner's Guide*. Packt Publishing Ltd., UK, 2011.
3. Tantau,T. User Guide to the Beamer Class, http://latex-beamer.sourceforge.net.
4. Oetiker,Tobias. The Not So Short Introduction to LATEX2E, https://tobi.oetiker.ch/lshort/lshort.pdf.

NUMERICAL PROGRAMMING IN C

(SPMMAT 01 02 02 GEC 2124)

This course is based on the following courses:

NUMERICAL METHODS: SPMMAT 01 01 02 GEC 3104

PROGRAMMING IN C: SPMMAT 01 01 03 GEC 2124

DISCRETE MATHEMATICS

(SPMMAT 01 02 03 GEC 3104)

UNIT-I

Mathematical Logic: Statement and notations, proposition and logic operations, connectives (conjunction, disjunction, negation), statement formulas and truth tables, propositions generated by set, equivalence of formulas and implication laws of logic, mathematical systems, propositions over a universe, principal of mathematical induction, variables, quantifiers.

UNIT-II

Relation and Function: Binary relations, Properties of binary relation in a set, Equivalence relations, Composition of binary relations, Partial ordering and Partial Order set, Hasse diagram, Function and Pigeon hole Principle. Recursion definition, many faces of recursion, Recurrence relations, common recurrence relations, generating functions and their solutions.

UNIT-III

Posets, lattice and basic properties of Boolean algebraic, Principle of duality, distributive and complemented lattices, uniqueness of finite Boolean algebra, Boolean functions and Boolean expressions, Normal forms of Boolean expression and simplifications of Boolean expressions, Basic circuits and theorems, Logical gates and relations of Boolean function.

UNIT-IV

Basic terminology of graph theory, Paths, Circuits, Graph connectivity, Eulerian paths, Multigraphs, Weighted graphs. Trees, Spanning trees, Binary trees, Rooted trees. Planar graphs, Eulers theorem. The Konigsberg Bridge problem and Eulerian graphs,Hamiltonian graphs.

Suggested Readings:

1. Rosen, K. H. *Discrete Mathematics and Its Applications*. 7th edition, Tata McGraw Hill, 2011.
2. Trembley, J. P. and Manohar, R. *A First Course in Discrete Structure with applications to Computer Science*. Tata McGraw Hill, 1999.
3. Khanna, V. K. *Lattices and Boolean Algebras*. PHI Publication, 2004.
4. Liu, C. L. *Elements of Discrete Mathematics.* Tata McGraw Hill, 2000.
5. Ram, B. Discrete Mathematics, Pearson Education, 2012.
6. Lipschutz, S., Lipson, M. L. and Patil, V. H. *Discrete Mathematics.* Schaum's Outline Series, Tata McGraw-Hill Education, 2006.

SEMESTER – III

INTEGRAL EQUATIONS

(SPMMAT 01 03 01 C 3104)

UNIT - I

Linear integral equations: Volterra integral equations, Fredholm integral equations, Some basic identities, Types of kernels: Symmetric kernel, Separable kernel, Iterated kernel, resolvent kernel, Initial value problems reduced to Volterra integral equations, Solution of Volterra integral equation using: Resolvent kernel, Successive approximation, Neumann series method.

UNIT- II

Boundary value problems reduced to Fredholm integral equations, Solution of Fredholm integral equations using separable kernel, resolvent kernel. Methods of successive approximation and successive substitution to solve Fredholm equations of second kind. Solution of Homogeneous Fredholm integral equation: Eigen values, eigen vectors,

UNIT - III

Integral transforms for solving integral equations: Basic properties of Laplace transforms, Solution of Abel's equation using Laplace transform, Application of Laplace transform to the Solution of Volterra integral equations with convolution type kernels, Solution of integro-differential equations using Laplace transform.

UNIT - IV

Green's function, Basic four properties of the Green's function, Procedure for construction of the Green's function by using its basic four properties, Construction of Green's function for boundary value problems, Solution of boundary value problems using Green's function, Reducing boundary value problems to an integral equation using Green's function.

Suggested Readings:

1. Kanwal, R.P. *Linear Integral Equation. Theory and Techniques*. Academic Press, 2014.
2. Raisinghania M. D. *Integral Equation & Boundary Value Problem.* S. Chand Publishing, 2007.
3. Jerri, A. *Introduction to Integral Equations with Applications*, John Wiley & Sons, 1999.
4. Hildebrand, F. B. *Method of Applied Mathematics*, Courier Corporation, 2012.
5. Wazwaz, A. M. *A First Course in Integral Equations*. World Scientific Publishing Co Inc, 1997.

FUNCTIONAL ANALYSIS

(SPMMAT 01 03 02 C 3104)

UNIT-I

Normed linear spaces. Banach spaces. Examples of Banach spaces and subspaces. Continuity of linear maps. Equivalent norms. Normed spaces of bounded linear maps. Bounded linear functionals. Dual spaces of l^p, $\mathbb{R}^n$and Reflexivity.

UNIT-II

Hilbert spaces, examples, Orthogonality, Orthonormal sets, Bessel's inequality, Parsevals's theorem. The conjugate space of a Hilbert space.

UNIT-III

Adjoint operators, Self-adjoint operators, Normal and Unitary operators, Weak convergence. Completely continuous operators.

UNIT-IV

Hahn-Banach theorem and its applications, Uniform boundedness principle. Open mapping theorem, Projections on Banach spaces, closed graph theorem.

Suggested Readings:

1. Kreyszig, E. *Introductory Functional Analysis with Applications*. John Wiley, 2007.
2. Simmons, G. F. *Introduction to Topology and Modern Analysis*. McGraw-Hill Pvt. Ltd. 2016.
3. Bachman, G. and Narici, L. *Functional Analysis*. Courier Corporation, 2012.
4. Royden, H. L. *Real Analysis*. MacMillan Publishing Co., Inc., New York, 4th edition, 1993.
5. Conway, J. B. *A course in functional analysis*. Springer, 2010.

OPERATIONS RESEARCH

(SPMMAT 01 03 03 C 3104)

UNIT - I

Operations Research: Origin, definition and scope. Linear Programming: Formulation and solution of linear programming problems by graphical, simplex methods, Big - M and two phase methods, Degeneracy, Duality in linear programming, sensitivity analysis.

UNIT - II

Transportation Problems: Basic feasible solutions, optimum solution by stepping stone and modified distribution methods, unbalanced and degenerate problems, transhipment problem. Assignment problems: Solution by Hungarian method, unbalanced problem, case of maximization, travelling salesman and crew assignment problems.

UNIT - III

Queuing models: Basic components of a queuing system, General birth-death equations, steady-state solution of Markovian queuing models with single and multiple servers (M/M/1. M/M/C, M/M/1/k, M/MC/k)

UNIT- IV

Game Theory: Two person zero sum game, Game with saddle points, rule of dominance; Algebraic, graphical and linear programming, concept of mixed strategy. Sequencing problems: Processing of n jobs through 2 machines, n jobs through 3 machines, 2 jobs through m machines, n jobs through m machines.

Suggested Readings:

1. Swarup, K. and Gupta, P. K. *Operations Research*. S. Chand publisher, 1978.
2. Taha, H. A. *Operation Research: An Introduction.* Prentice Hall of India, 1997.
3. Gupta, P.K. and Hira, D.S. *Introduction to Operations Research,* S. Chand & Co. 2008.
4. Sharma, S. D. Operation Research, Kedar Nath Ram Nath Publications, 1974.
5. Sharma, J. K., *Mathematical Model in Operation Research*, Tata McGraw Hill, 1989.

NUMBER THEORY

(SPMMAT 01 03 04 C 3104)

UNIT - I

Representation of the real numbers by decimals, Divisibility, G.C.D and L.C.M., Primes, Fermat numbers, congruences and residues, theorems of Euler, Fermat and Wilson, solutions of congruences, linear congruences, Chinese remainder theorem,

UNIT -II

Arithmetical functions $\varphi(n)$, $\mu(n)$ and $d(n)$ and $\sigma(n)$, Mobius inversion formula, congruences of higher degree, congruences of prime power modulli and prime modulus, power residue,

UNIT - III

Quadratic residue, Legendre symbols, lemma of Gauss and reciprocity law. Jacobi symbols, irrational numbers, irrationality of e and π. Finite continued fractions, simple continued fractions, infinite simple continued fractions.

UNIT - IV

Periodic continued fractions, Approximation of irrational numbers by convergents, best possible approximation, Farey series, rational approximation, Pell's equations, Hurwitz theorem, Lagrange four square theorem.

Suggested Readings:

1. Burton, D. M. *Elementary Number Theory*. Tata McGraw Hill Publishing House, 2006.
2. Apostol, T. M. *Introduction to Analytic Number Theory*. Springer 2014.
3. Davenport, H. *Higher Arithmetic*. Cambridge University Press, 1999.
4. Hardy, G. H. and Wright, E. M. *Theory of Numbers*. Oxford Science Publications, 2003.
5. Niven, I. and Zuckerman, H. S. *Introduction to the Theory of Numbers*. John Wiley & Sons, 2008.

MECHANICS

(SPMMAT 01 03 05 C 3104)

UNIT-I

Moments and products of Inertia, Theorems of parallel and perpendicular axes, principal axes, The momental ellipsoid, Equimomental systems, Coplanar distributions.

UNIT-II

Generalized coordinates, Holonomic and Non-holonomic systems. Scleronomic and Rheonomic systems. Lagrange's equations for a holonomic system, Lagrange's equations for a conservative and impulsive forces. Kinetic energy as quadratic function of velocities. Generalized potential, Energy equation for conservative fields.

UNIT-III

Hamilton's variables. Donkin's theorem. Hamilton canonical equations. Cyclic coordinates. Routh's equations. Poisson's Bracket. Poisson's Identity. Jacobi-Poisson Theorem. Hamilton's Principle. Principle of least action.

UNIT-IV

Poincare Cartan Integral invariant. Whittaker's equations. Jacobi's equations. Statement of Lee Hwa Chung's theorem. Hamilton-Jacobi equation. Jacobi theorem. Method of separation of variables. Lagrange Brackets. Condition of canonical character of a transformation in terms of Lagrange brackets and Poisson brackets. Invariance of Lagrange brackets and Poisson brackets under canonical transformations.

Suggested Readings:

1. Chorlton, F. *Textbook of Dynamics.* CBS Publishers & Dist. Pvt. Ltd., 2004.
2. Gantmacher, F. *Lectures in Analytical Mechanics*. Mir Publishers, Moscow, 1975.
3. Louis N. H. and Janet D. F. *Analytical Mechanics*. Cambridge University Press, 1998.
4. Rao, S. K. *Classical Mechanics*. PHI Learning Pvt. Ltd., 2005
5. Spiegel, M. R. *Theoretical Mechanics,* Schaum Outline Series McGraw Hill, 1980.

DCEC COURSES OFFRED TO M.SC. (MATHEMATICS) STUDENTS ONLY

WAVELET ANALYSIS

(SPMMAT 01 03 01 DCEC 3104)

UNIT-I

Review of Inner Product spaces, orthonormal systems. Frames in C^n. Frames algorithms. Frames and Bessel sequences in infinite dimensional Hilbert spaces, Frame sequence, the Gram matrix associated with Bessel sequences.

UNIT-II

Frames and Operators, characterization of frames, dual frames, tight frames. Riesz bases, Frames versus Riesz bases, conditions for a frame being a Riesz basis, frames containing a Riesz basis. Perturbation of frames.

UNIT-III

Wavelets, Haar Wavelets, basic properties of the Haar scaling function, Haar decomposition And reconstruction algorithms. The Daubechies wavelets, wavelet bases, scaling function. Multiresolution analysis (MRA). Construction of wavelets from MRA.

UNIT-IV

Windowed Fourier Transform (WFT). Continuous Fourier Transform (CFT). Continuous Wavelet Transform (CWT). Comparison between CFT and CWT. Continuous Wavelet Transform as an operator. Inversion formula for Continuous Wavelet Transform.

Suggested Readings:

1. Christensen, O. *An Introduction to Frames and Riesz Bases*. Birkhauser, 2003.
2. Mallat, S. *A Wavelet Tour of Signal Processing*. Academic Press, 2009.
3. Harnendez, E. and Weiss, G. *A First Course on Wavelets*, CRC Press, 1996.
4. Han, D., Kornelson, K., Larson, D. and Weber, E. *Frames for Undergraduates*, Student Math.Lib.,(AMS) Vol. 40, 2007.
5. Boggess and Narcowich, F.J. *A First Course in Wavelets and Fourier Analysis*. Wiley, 2009.

OBJECT ORIENTED PROGRAMMING WITH C++

(SPMMAT 01 03 02 DCEC 2124)

UNIT - I

Basic concepts of Object-Oriented Programming (OOP). Advantages and applications of OOP. Object-oriented languages. Introduction to C++. Structure of a C++ program. Creating the source files. Compiling and linking. C++ programming basics: Input/Output, Data types, Operators, Expressions, Control structures, Library functions.

UNIT - II

Functions in C++ : Passing arguments to and returning values from functions, Inline functions, Default arguments, Function overloading. Classes and objects : Specifying and using class and object, Arrays within a class, Arrays of objects, Object as a function arguments, Friendly functions, Pointers to members.

UNIT - III

Constructors and destructors. Operator overloading and type conversions. Inheritance: Derived class and their constructs, Overriding member functions, Class hierarchies, Public and private inheritance levels. Polymorphism, Pointers to objects, this pointer, Pointers to derived classes, virtual functions.

UNIT - IV

Streams, stream classes, Unformatted I/O operations, Formatted console I/O operations, Managing output with manipulators. Classes for file stream operations, Opening and Closing a file. File pointers and their manipulations, Random access. Error handling during file operations, Command-line arguments. Exceptional handling.

Suggested Readings:

1. Balagrusamy, E. *Object Oriented Programming with C++*. 2nd edition, Tata McGraw Hill Pub. Co, 2013.
2. Lafore, I. S. R. *Object Oriented Programming using C++*. Waite's Group Galgotia Pub, 1994.
3. Gottfried, B. S. *Object Oriented Programming using C++*. Schaum's Outline Series, Tata McGraw Hill Pub. Co., 2000.
4. Barakaki, J. N. *Object Oriented Programming using C++*. Prentice Hall of India, 1996.

INFORMATION THEORY

(SPMMAT 01 03 03 DCEC 3104)

UNIT-I

Measure of Information – Axioms for a measure of uncertainty. The Shannon entropy and its properties. Joint and conditional entropies. Transformation and its properties. Axiomatic characterization of the Shannon entropy due to Shannon and Fadeev.

UNIT-II

Noiseless coding - Ingredients of noiseless coding problem. Uniquely decipherable codes. Necessary and sufficient condition for the existence of instantaneous codes. Construction of optimal codes.

UNIT-III

Discrete Memoryless Channel - Classification of channels. Information processed by a channel. Calculation of channel capacity. Decoding schemes. The ideal observer. The fundamental theorem of Information Theory and its strong and weak converses.

UNIT-IV

Continuous Channels - The time-discrete Gaussian channel. Uncertainty of an absolutely continuous random variable. The converse to the coding theorem for time-discrete Gaussian channel. The time-continuous Gaussian channel. Band-limited channels.

Suggested Readings:

1. Ash, R. B. *Information Theory*. Courier Corporation, 2012.
2. Reza, F.M. *An Introduction to Information Theory*. Courier Corporation, 2012.
3. Aczel, J. and Daroczy, Z. *On Measures of Information and their Characterizations.* Academic Press, New York, 1975.
4. Hankerson, H. D., Harris, G. A. and Johnson, P. D. *Introduction to Information Theory and Data Compression*. Chapman and Hall/CRC, 2nd edition, 2003.

APPLIED DISCRETE MATHEMATICS

(SPMMAT 01 03 04 DCEC 3104)

UNIT-I

Formal Logic: Statements, Proposition, Symbolic Representation and Tautologies, Quantifiers, Proposition Logic.

UNIT-II

Lattices - Lattices as partially ordered sets, Their properties, Lattices as Algebraic systems, Some special Lattices, e.g., complete, complemented and Distributive Lattices. Sets Some Special Lattices e.g., Bounded, Complemented & Distributive Lattices.

UNIT-III

Boolean Algebra - Boolean Algebra as Lattices, Various Boolean Identities, The Switching Algebra example, Join - irreducible elements, Atoms and Minterms, Boolean Forms and Their Equivalence, Minterm Boolean Forms, Sum of Products canonical Forms, Minimization of Boolean Functions, Applications of Boolean Algebra to Switching Theory (using AND, OR and NOT gates).

UNIT-IV

Graph Theory - Definition of Graphs, Paths, Circuits, Cycles and Subgraphs, Induced Subgraphs, Degree of a vertex, Connectivity, Planar Graphs and their properties, Trees, Euler's Formula for Connected Planar Graph, Complete and Complete Bipartite Graphs.

Suggested Readings:

1. Kenneth H. R. *Discrete Mathematics and Its Applications,* 7th edition, Tata McGraw Hill, 2011.
2. Tremblay, J. P. & Manohar, R. *Discrete Mathematical Structures with Applications to Computer Science*. McGraw Hill Book Co., 1997.
3. Lepschutz, S. and Lipson, M. *Linear Algebra*. 5th edition, Tata McGraw Hill 2012.
4. Liu, C. L. *Elements of Discrete Mathematics*. Tata McGraw Hill, 2000.
5. Ram, B. *Discrete Mathematics*. Pearson Education, 2012.

FINITE ELEMENT ANALYSIS

(SPMMAT 01 03 05 DCEC 3104)

UNIT I

General theory of finite element methods, Difference between finite element and finite difference methods, Review of some integral formulae, Concept of discretization, Different coordinates, one dimensional finite elements, concept of shape functions, stiffness matrix, connectivity, boundary conditions, and equilibrium equation.

UNIT II

Numerical integration, Construction of shape functions: Linear elements (One dimensional bar element, two dimensional-Triangular and rectangular elements, three dimensional tetrahedron element).

UNIT III

Higher order elements: One dimensional quadratic element, Two dimensional triangular element, Rectangular element, three dimensional tetrahedron element: quadratic element and higher order elements

UNIT IV

Weighted residual and variational approaches (Galerkin method, collocation method, Rayleigh Ritz method etc.), Solving one-dimensional problems.

Application of finite element methods for solving various boundary value problems, Computer procedures for Finite element analysis.

Suggested Readings:

1. Rao, S. S. *The Finite Element Method in Engineering*. 5th edition, Butterworth-Heinemann;, 2017.
2. Zienkiewicz, O. C. and Taylor, R. L. *The Finite Element Method: The Basis.* Butterworth-Heinemann, 2000.
3. Smith, G. D. *Numerical solution of Partial Differential Equations: Finite difference methods*. Oxford Applied Mathematics and Computing Science Series, 1985.
4. Hughes, T. J. R. *The Finite Element Method (Linear Static and Dynamic Finite Element Analysis)*. Courier Corporation, 2007.

SEMESTER – IV

DIFFERENTIAL GEOMETRY

(SPMMAT 01 04 01 DCEC 3104)

UNIT-I

Curves with torsion: Tangent, Principal Normal, Curvature, Binormal, Torsion, Serret Frenet formulae, Locus of centre of spherical Curvature. Helix, Involutes and Evolutes,

UNIT-II

Envelopes: Surfaces, Tangent plane, Envelope, Characteristics, Edge of regression, Developable surfaces, Osculating, Polar and Rectifying developable

UNIT-III

Curvilinear Co-ordinates: First order magnitude, Directions on a surface, Second order magnitudes, Derivative of unit normal, Principal directions and curvatures.

UNIT-IV

Geodesics: Geodesic property, Equations of geodesics, Torsion of a geodesic. Bonnet's Theorem, Joachimsthal's theorems, Geodesic parallels, Geodesic ellipses and hyperbolas, Liouville surfaces.

Suggested Readings:

1. Weatherburn, C. E. *Differential Geometry of Three Dimensions*, Cambridge University Press, 2016.
2. Wilmore T. J. *An Introduction to Differential Geometry*, Dover Publications Inc., 2012.
3. Graustein, W. C. *Differential Geometry*. Courier Corporation, 2012.
4. Pressley, A. *Elementary Differential Geometry*. Springer, 2002.

MATHEMATICAL MODELING

(SPMMAT 01 04 02 DCEC 3104)

Unit-I

Simple situations requiring mathematical modelling, techniques of mathematical modeling, Classifications, Characteristics and limitations of mathematical models, Some simple illustrations. Mathematical modelling in population dynamics, Mathematical modelling of epidemics through systems of ordinary differential equations of first order Mathematical Models in Medicine, Battles and international Trade in terms of Systems of ordinary differential equations.

Unit-II

The need for Mathematical modelling through difference equations, linear growth and decay models, Non-linear growth and decay models, Basic theory of linear difference equations with constant coefficients, Mathematical modelling through difference equations in economics and finance.

Unit-III

Mathematical modelling through difference equations in population dynamics and genetics. Mathematical Modelling through difference equations in probability theory. Miscellaneous examples of Mathematical modelling through difference equations.

Unit-IV

Situations that can be modelled through graphs, Mathematical models in terms of directed graphs Mathematical models in terms of signed graphs, Mathematical models in terms of weighted graphs.

Suggested Readings:

1. Kapur J. N. *Mathematical Modelling*, New Age International, 1988.
2. Rutherford, A. *Mathematical Modelling Techniques.* Courier Corporation, 2012.
3. Bender, E. A. *An Introduction to Mathematical Modelling.* Courier Corporation, 2000.
4. Clive, L. D. *Principles of Mathematical Modelling.* Elsevier, 2004.
5. Meerschaert, M. M. *Mathematical Modelling.* Academic Press, 2013.

ADVANCED NUMERICAL ANALYSIS

(SPMMAT 01 04 03 DCEC 3104)

UNIT-I

General iterative method for the system: x = g(x) and its sufficient condition for convergence. Chebychev method, Ramanujan's method, Methods for getting complex roots, Interpolation at irregular intervals, Hermite interpolation, Spline interpolation: B-splines, Eigen-value problems.

UNIT-II

Review of finite difference operators, Difference equations, order of difference equation, degree of difference equation, Solution of difference equations, Use of generating function in the solution of difference equation.

Unit III

Finite difference methods for PDEs, Elliptic parabolic, Hyperbolic equations: Implicit difference methods for wave equation solution of advection equation by finite difference method and Maccormack method, stability analysis, Lax, Wendroff explicit method on rectangular mesh for 1st order equations.

Unit IV

Fourier analysis and Wavelet analysis .The Fourier transform and its applications. Wavelets, Haar Wavelets, continuous Wavelet transforms, discrete Wavelet transforms, multi resolutions Wavelet transforms, Algebra and geometry of Wavelet – matrices, one dimensional wavelet systems.

Suggested Readings:

1. Atkinson, K. and Han, W. *Theoretical Numerical Analysis*, Springer Science & Business Media, 2009.
2. Smith, G. D. *Numerical solution of Partial Differential Equations: Finite Difference Methods, 3rd edition.* New York: Oxford University Press, 1985.
3. Bradie, B. *A friendly introduction to Numerical Analysis.* Delhi: Pearson Education, 2007.
4. Reddy, J. N. *An Introduction to Finite Element Methods.* Delhi: McGraw-Hill, 2000.
5. Bazaraa, M.S., Sherali, H.D. and Shetty, C.M. *Nonlinear Programming Theory and Algorithms.* Delhi: John Wiley and Sons, 2004.

THEORY OF ELASTICITY

(SPMMAT 01 04 04 DCEC 3104)

UNIT-I

Cartesian Tensor: Coordinate transformation, Cartesian Tensor of different order, Sum or difference and product of two tensors. Contraction theorem, Quotient law, Symmetric & Skew symmetric tensors, Kronecker tensor, alternate tensor and relation between them, Scalar invariant of second order tensor, Eigen values & vectors of a symmetric second order tensor, Gradient, divergence & curl of a tensor field. Analysis of Strain: Affine transformations. Infinitesimal affine deformation. Geometrical interpretation of the components of strain.

UNIT-II

Strain quadric of Cauchy. Principal strains and invariants. General infinitesimal deformation. Saint-Venant's equations of Compatibility, Analysis of stress: Stress tensor. Equation of equilibrium. Transformation of co-ordinates. Stress quadric of Cauchy. Principal stress and Invariants. Maximum normal and shear stresses.

UNIT-III

Equations of elasticity: Generalized Hooke's law. Homogeneous isotropic media. Elastic moduli for isotropic media. Equilibrium and dynamic equations for an isotropic elastic solid. Strain energy function and its connection with Hooke's law. Beltrami-Michell compatibility equations.

UNIT- IV

Two-dimensional problems. Plane stress. Generalized plane stress. Airy stress function. General solution of Biharmonic equation. Stresses and displacements in terms of complex potentials. Waves: Propagation of waves in an isotropic elastic sold medium. Waves of dilation and distortion. Plane waves. Elastic surface waves such as Rayleigh and Love waves.

Suggested Readings:

1. Sadd, M. H. *Elasticity*: *Theory, Applications and Numerics*. Academic Press, 2014.
2. Sokolnikoff, I.S. *Mathematical Theory of Elasticity*. McGraw-Hill Inc, 2nd revised edition, 1956.
3. Narayan, S. *Text Book of Cartesian Tensors*. S. Chand & Co., 1968.
4. Timoshenko, S. P. and Goodier, J. N. *Theory of Elasticity.* New York McGraw-Hill, 2010.
5. Love, A. E. H. *A Treatise on Mathematical Theory of Elasticity*. Cambridge [Eng.] University Press, 2013.

ADVANCED COMPLEX ANALYSIS

(SPMMAT 01 04 05 DCEC 3104)

UNIT-I

Maximum modulus principle, Schwarz's Lemma, Convex functions and Hadamard's Three Circles Theorem, Phragmen-Lindelof Theorem.

UNIT-II

The space of continuous functions, Spaces of analytic functions, The Riemann Mapping Theorem, Weierstrass Factorization Theorem. Gamma function, Reimann zeta function

UNIT-III

Analytic Continuation, Runge's Theorem, Simple connectedness, Mittag-Leffier's Theorem, Schwarz Reflection Principle. Analytic Continuation.

UNIT-IV

Basic Properties of harmonic functions, Harmonic functions on a disk, Jensen's Formula, Bloch's Theorem, The Little Picard Theorem, Schottky's Theorem, The Great Picard Theorem.

Suggested Readings:

1. Lang, S. *Complex Variable.* Springer, 2013.
2. Alpay, D. *A Complex Analysis Problem Book.* Birkhäuser, 2016.
3. Churchill, R. V. and Brown, J. W. *Complex Variables and Applications. 9th edition*, McGraw Hill Education, 2014.
4. Conway J. B. *Functions of One Complex Variable*. Springer, 1978.
5. Ahlfors, L.V. *Complex Analysis*. McGraw-Hill, 1979
6. Edward, S. B. and Snider, Arthur D. *Fundamental of Complex Analysis with Applications to Engineering and Sciences*. Pearson Education, 2014.

INTRODUCTIONS TO CRYPTOGRAPHY

(SPMMAT 01 04 06 DCEC 3104)

UNIT-I

Modular arithmetic, Congruence, Primitive roots, Cryptography Introduction, Caesar Cipher, Diffie-Hellman RSA public key cryptosystem, Knapsack Cryptosystem, Application of primitive roots to cryptography.

UNIT-II

Applications of Cryptography in Primality testing and Factorization of large composite numbers, Remote coin flipping. Elliptic curve based cryptography.

UNIT-III

Perfect numbers, Fermat numbers, Mersenne primes and Amicable numbers, Fibonacci Numbers, Representation of Integers as sum of Squares.

UNIT-IV

Linear and Non-linear Diophantine equations, Fermat's last Theorem, Prime Number Theorem and Zeta function.

Suggested Readings:

1. Burton , D. M. *Elementary Number Theory*, Tata McGraw Hill Publishing House, 2006.
2. Menezes, A. J., V., Oorschot, P. C. and Vanstone, S. A. *Handbook of Applied Cryptography*. CRC Press, 1996.
3. Koblitz, N. *A Course in Number Theory and Cryptography*. Springer 1987.
4. Buchmann, J. A. *Introduction to Cryptology*. Springer Science & Business Media, 2012
5. Simmons, G. J. *Contemporary Cryptology, The Science of Information Integrity*. New York, IEEE Press, 1992
6. Tilborg, H. C. A. *Fundamentals of Cryptology*. Springer 2013.

ADVANCED ABSTRACT ALGEBRA

(SPMMAT 01 04 07 DCEC 3104)

UNIT – I

Cyclic modules, Simple and semi-simple modules, Schur's lemma, Free modules, Fundamental structure theorem of finitely generated modules over principal ideal domain and its applications to finitely generated abelian groups.

UNIT - II

Uniform modules, Primary modules and Neother- Lasker theorem. Neotherian and Artinian modules and rings with simple properties and examples.

UNIT – III

Nilpotent ideals in Neotherian and Artinian rings, Hilbert Basis theorem, Nakayama's lemma, Nilradical and Jacobson radicals, Opertions on ideals, Extension and contraction.

UNIT – IV

Hom(R,R), Opposite rings, Wedderburn - Artin theorem, Maschk's theorem, Equivalent statement for left Artinian rings having non-zero nilpotent ideals.

Suggested Readings:

1. Rotman, J. J. *Advanced Modern Algebra. 3rd edition*. American Mathematical Soc., 2015.
2. Bhattacharya, P. B., Jain, S. K. and Nagpaul, S. R. *Basic Abstract Algebra*. 2nd edition, Cambridge University Press, Indian edition, 1997.
3. Atiyah, M. F. and Macdonald, I. G. *Introduction to Commutative Rings.* Sarat Book House, 2007.
4. Cohn, P. M. *Algebra, Vols. I, II & III*, John Wiley & Sons, (Vol. I-1982, Vol. II- 1989, Vol-III- 1991).
5. Curtis, C. W. and Reiner, I. *Representation Theory of finite Groups and Associative Algebras*. Wiley, 1988.
6. Anderson, F. W. and Fuller, K. R. *Rings and Categories of Modules.* Springer-Verlag New York, 1992.
7. Lam, T. Y. *Lectures on Modules and Rings*. GTM Vol. 189, Springer-Verlag, 1999.

MEASURE THEORY AND INTEGRATION

(SPMMAT 01 04 08 DCEC 3104)

UNIT - I

Length of an open set, concept of measure, Lebesgue outer measure and measurable sets, example of non-measurable set, sigma algebra, Borel sets, G_δ and F_σ –sets, outer and inner regularity of Lebesgue measure.

UNIT - II

Set function, abstract measure spaces, properties of measures, some examples of measures, measurable spaces, measurable functions, combinations of measurable functions, limits of measurable functions.

UNIT- III

Review of Riemann integral, integrable simple functions, the Lebesgue integration of a measurable function, integration with respect to a measure.

UNIT - I V

Almost everywhere convergence, convergence in measure, Fatou's Lemma, Monotone and Dominated Convergence Theorems.

Suggested Readings:

1. Barra, G. de. *Measure Theory and Integration*. New Age International (P) Ltd., 2009.
2. Berberian, S. K. *Measure and Integration*. AMS Chelsea Publications, 2011.
3. Royden, H. L. and Fitzpatrick P. M. *Real Analysis*. 4th edition, Pearson India, 2010.
4. Rana, I. K. *An Introduction to Measure and Integration*. 2nd edition, Narosa Publishing House, 2004.
5. Hewitt, E. and Stromberg, K. *Real and Abstract Analysis*. Springer-Verlag, New York, 1975.
6. Folland, G. B. *Real Analysis.* John Wiley & Sons, Inc., New York, 1999.

SKILL ENHANCEMENT ELECTIVCE COURSES

Department may also offer skill enhancement courses besides the following two courses depending on the availability and expertise of the faculty members in the Department.

PROGRAMMING IN MATLAB

(SPMMAT 01 04 01 SEEC 0120)

UNIT-I

Overview of MATLAB, operators, Display format, elementary built-in functions, working with variables, General commands, data types, data import, arrays, operations with arrays.

UNIT-II

Matrices: Eigenvalues and Eigenvectors, Similarity Transformation and Diagonalization, Functions, Script files, operators, Loops and Conditional Statements, Programming in MATLAB, Graphics- 2-D and 3-D Plots, input and output.

UNIT-III

Applications in Numerical Methods: System of linear equations, L U Decomposition, Gauss elimination method, Gauss Seidel Method, Gauss Jordan Method. Interpolation: Lagrange and Newton Polynomials, curve fitting, Bisection Method, False Position (Regula-Falsi) Method, Newton–Raphson) Method, Secant Method, Newton Method for a System of Nonlinear Equations, Symbolic Solution for Equations.

UNIT-IV

Applications to Numerical differentiation and integrations: Trapezoidal Method and Simpson Method, Runge–Kutta Method, Introduction to working with modules in MATLAB.

***Suggested Readings*:**

1. Yang, W. Y., Cao, W., Chung, T. S. and Morris, J. *Applied Numerical Methods using MATLAB.* John Wiley & Sons, 2007.
2. Otto, S. R. and Denier, J. P. *An Introduction to Programming and Numerical Methods in MATLAB.* Springer Science & Business Media, 2005
3. Rudra P. *Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers*, Oxford University Press, 2002.
4. Getting started with Matlab, Maths Works Inc. www. in.mathsworks.com

TYPESETTING IN LATEX

(SPMMAT 01 04 02 SEEC 0120)

UNIT I

Preparing an input file, sentences and paragraphs, the document class, sectioning, display material, running LaTeX, changing the type style, producing mathematical symbols and mathematical formulae, arrays, delimiters, multiline formulae, putting one thing on other, spacing in math mode.

UNIT II

Defining command and environments, Producing and including graphics in a LaTeX file, figures and other floating bodies, lining it up in columns, table of content, cross-reference, bibliography and citation, making index and glossary, slides, overlays and notes, letters.

UNIT III

Design it yourself: document class, page style, title page, customizing the style, line and page breaking, numbering, length, spaces and boxes, formatting with boxes, centring and flushing, list making environments, changing font type size and special symbols, picture, picture environments, picture objects, text, boxes, straight lines, arrow, stacks, circles, oval, framing, curve, grid, repeat patterns.

UNIT IV

Making presentation slides in beamer class LaTeX, various styles in beamer presentation, dynamic slides. PostScript macros for Generic TeX (PsTrix): arguments, dimension, coordinates, angles, line styles, fill styles, custom styles, custom graphics, picture tools, text tricks, node and connection special tricks. Basics of MathJax, Mathjax configuration options.

***Suggested Readings*:**

1. Leslie L. *A Document Preparation System: User's Guide and Reference Manual*. Addison-Wesley Publishing Company, 2001.
2. Stefan K. *LaTeX Beginner's Guide*, Packt Publishing Ltd, 2011
3. Tantau, T. *User Guide to the Beamer Class*, http://latex-beamer.sourceforge.net.
4. Tobias O. *The Not So Short Introduction to LATEX2E*. https://tobi.oetiker.ch/lshort/lshort.pdf