MS 539 Advanced Numerical Analysis **(L3 –T1 –P0 –CH -CR 4)**

Unit-1

Finite Difference method: Explicit and Implicit schemes, consistency, stability and convergence, Lax equivalence theorem. Numerical solutions of elliptic, parabolic and hyperbolic partial differential equations.

Unit-2

Optimization: Problem formulation, single variable optimization, multi variable optimization.

Unit-3

Krylov subspace methods, Conjugate-Gradient (CG), BiConjugate-Gradient (BiCG), BiCG Stabilised (BiCGStab), Generalised Minimum Residual (GMRES). Preconditioning Techniques, parallel implementations.

Unit-4

Approximate method of solution: Galerkin method, properties of Galerkin aproximations, Petrov-Galerkin method, Generalised Galerkin method.

Unit-5

Review of Sobolev spaces. Weak solution of elliptic boundary value problem, regularity of weak solutions, maximum principle.

Finite Element method: Definition and properties. Element types triangular, rectangular, quadrilateral. Application of finite element method for second order problems, one and two dimensional problems. Isoparametric finite element, non-conformal finite element. Mixed finite element.

Textbook(s)

1. Watkins, D. S. *Fundamental of Matrix Computations*, 2nd edition (WileyInterscience, 2002).
2. Smith, G. D. Numerical *Solution of Partial Differential Equations: Finite Difference Methods*, 3rd edition (Oxford University Press, 1986).
3. Reddy, J. N. *An Introduction to the Finite Element Method*, 3rd Edition (McGraw Hill India, 2006).

Reference book(s)

1. Trefethen, L. N and Bau, David *Numerical Linear Algebra* (SIAM, 1997).
2. Hoffman, Joe D. *Numerical Methods for Engineers and Scientist*, 2nd edition (Mc-Graw Hill 2004).
3. Ciarlet, P. G. *The Finite Element Method for Elliptic Problems* (North Holland, 1978).
4. Johnson, C.*Numerical Solution of Partial Differential Equations by the Finite Element Method* (Cambridge University Press, 1987).

MS 569 Coding Theory I **(L3-T1-P0-CH4-CR4) Unit - 1**

Comminication channel, Introduction to coding theory, types of codes, ISBN code, Barcodes, Digital codes, Group Theory, Vector spaces over arbitrary fields with examples, linear block codes, Dual codes, Distance of block codes, Standard array, Syndrome decoding and Decoding by coset leaders.

Unit – 2

Error-correction and detection capabilties of linear block codes. Singleton bound, Greismer bound, Plotkin bound, Hamming sphere packing bound, Varshamov-Gilbert-Sacks bound.

Unit - 3

Weight Enumerators and the MacWilliams Theorem, Type of errors, Burst errors, Bounds for burst-error detecting and correcting codes.

Unit - 4

Some Interesting Block Codes and Their Properties: Perect codes, Hamming codes, Golay codes, Hadamard codes, Product codes, Reed-Muller codes, Maximum–Distance Separable (MDS) codes.

Text Book(s):

1. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.

2. Torleiv Klove, Codes for error Dectection, Series on Coding Theory and Cryptology, vol. 2, World Scientific Publishing Co. Pte. Ltd., 2007

Reference Book(s):

1. Raymond Hill, A First Course in Coding Theory, Oxford University Press, 1990.

2. J.H. Van Lint, Introduction to Coding theory, Graduate Texts in Mathematics, 86, Springer, 1998.

3. A. Neubauer, J. Freudenberger, V. Kuhn, Coding Theory: Algorithms, Architectures and Applications, John Wiley & Sons Ltd, England, 2007.

4. L.R. Vermani, Elements of Algebraic Coding, Chapman and Hall, 1996.

5. W. C. Huffman and V. Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.

6. Shu Lin and Daniel J. Costello, Error Control Coding-Fundamentals and Applications, Pearson Education India, 2011.

MS 570 Coding Theory II **(L3-T1-P0-CH4-CR4)**

(Prerequisite Coding Theory I)

Unit – 1

Zero of polynomials, Algebraic extension of a field, Galios field, Primitive elements, Minimum polynomials, order, Multiplcative group of a Galios fields, structure of finite fields.

Unit – 2

Error detection with cyclic codes, Error-correction procedure for cyclic codes, Shortended cyclic codes, Pseudo cyclic codes. Code symmetry, Invariance of codes under transitive group of permutations. **Unit - 3**

BCH codes, Minimum distance and BCH Bounds, Decoding of BCH codes, Reed-Solomon codes. **Unit - 4**

Tree codes, Convolutional codes, Description of linear tree and convolutional codes by matrices, distance for convolutional codes, Maximum likelihood decoding of Convolutional codes, Vitorbi decoding algorithm.

Text Book(s):

1. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.

2. Shu Lin and Daniel J. Costello, Error Control Coding-Fundamentals and Applications, Pearson Education India, 2011.

Reference Book(s):

1. Man Young Rhee, Error Correcting Coding Theory, McGraw-Hill Publishing, 1989.

2. Robert H. Morelos-Zaragoza, The art of Error Correcting Codes, 2nd Edition, John Wiley & Sons Ltd, England, 2006.

3. A. Neubauer, J. Freudenberger, V. Kuhn, Coding Theory: Algorithms, Architectures and Applications, John Wiley & Sons Ltd, England, 2007.

4. L.R. Vermani, Elements of Algebraic Coding, Chapman and Hall, 1996.

5. Jiri Adamek, Foundations of Coding: Theory and Applications of Error-Correcting Codes with an Introduction to Cryptography and Information Theory, John Wiley & Sons, USA, 1991.

6. W. C. Huffman and V. Pless, Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.

MS 401: Abstract Algebra (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

External direct product of groups, properties of external direct products, internal direct products, fundamental theorem of finite abelian groups and applications. **Unit-2**

Group action, properties of group action, class equation of finite groups, Sylow's theorems, applications of Sylow's theorems.

Unit-3

Subnornmal, normal series, derived group, solvable groups, composition series, nilpotent groups, Jordan-Holder theorem.

Unit-4

Word, reduced word, free group, rank of a free group, fundamental theorem of free groups, presentation of groups.

Unit-5

Polynomial rings, rings of formal power series, embedding theorems, field of fractions.

Unit-6

Factorization theory in integral domains, PID, UFD and Euclidean domains. **Unit-7**

Field extensions, algebraic and transcendental elements, geometrical constructions, splitting field, finite fields, structure of finite fields, normal, separable and inseparable extension of fields.

Textbook(s):

1. Gallian, J. A., *Contemporary Abstract Algebra*, 4th edition (Narosa Publishing house, New Delhi, 2009).
2. Dummit, D. S. & Foote, R. M., *Abstract Algebra*, 3rd edition (John Wiley & Sons, Indian reprint, New Delhi, 2011).
3. Herstein, I. N., *Topics in Algebra*, 2nd edition (John Wiley & Sons, Indian reprint, New Delhi, 2006).

Reference book(s):

1. Fraleigh, J. B. *A First Course in Abstract Algebra*, 7th edition (Pearson Education India, New Delhi, 2008).
2. Lang, S. *Algebra*, 3rd edition (Springer India, New Delhi, 2006).

MS 405: Real Analysis **(L3-T1-P0–CH4-CR4)**

Unit- 1

Sequence of functions, pointwise and uniform convergence, interchange of limits. Functions of bounded variation. Reimann Stieltjes integral. Integration by parts

Unit- 2

Compactness, Sequential compactness, Bolzano-Weierstrass Property, Totally bounded spaces, compactness and completeness, finite intersection property. Continuous functions on compact spaces. Characterization of complete metric spaces. Arzela Ascoli Theorem.

Unit- 3

Connectedness, intermediate value theorem, Completeness, Bolzano Weierstrass Theorem, nested set theorem. Fixed point theorem. Completion.

Unit- 4

Functions of several variables, directional derivatives, differentiability and total derivative. Jacobians, chain rule, higher order partial derivatives, Taylor's theorem. Inverse function theorem, Implicit function theorem, extremum problem with constraints, Lagrange's method of multiplier.

Text Books:

1. N. L. Carothers. Real Analysis.
2. W. Fleming. Functions of several variables **Reference:**
1. Apostol, T. M. Mathematical Analysis (Narosa Publishing House, 1985)
2. Simmons, G. F. Introduction to Topology and Modern Analysis (Tata McGraw Hill Book Co. Ltd.,1963).

MS 411: Computer Programming[+] **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Revision of fundamentals of C: Data types in C, variables in C, input output statements, constant declaration, arithmetic operators in C, arithmetic expressions, assignment statements, arithmetic assignment operators, increment and decrement operators, type conversions, operator precedence. for loop, while loop, do…while loop, if statement, if…else statement, switch statement, conditional operators. The break statement, the continue statement, the go-to statement.

Unit-2

Arrays: Arrays, declaration of one dimensional arrays, two dimensional arrays.

Structures and Unions: User defined data types, structures, array of structures, unions, enumerated data type.

Unit-3

Searching and Sorting: Bubble sort, selection sort, insertion sort, linear search and binary search. **Unit-4**

Function in C: Simple functions, passing arguments to functions with return value, call by value, call by reference, overloaded functions, inline functions, default arguments.

Unit-5

Pointers: Introduction; accessing address of a variable; pointer declaration, initialization, accessing variable through pointer, chain of pointers; pointer expressions, increment and scale factor. Pointers and Arrays. Array of pointers. Pointers as function arguments.

Unit-6

Files in C: Defining and opening a file, closing a file. Input/Output operations on files.

Unit-7

Dynamic Memory Allocation and Linked list: Dynamic memory allocation, Malloc, Calloc, Free, Realloc. Concepts of linked list, advantages of linked list, types of linked list. Creating a linked list.

Textbook(s)

1. Rajaraman, V. *Fundamentals of Computers* (Prentice Hall of India, New Delhi, 2002).
2. Balaguruswamy, E. *Programming in ANSI C* (Tata McGraw-Hill, 2004).

Reference book(s)

1. Kanetkar, Y. P. *Let us C* (BPB Publication, 2001).
2. Venkateshmurthy, M. G. *Programming Techniques through C* (Pearson Education, 2002).

[+] *Practical unit for the course MS 411 to be done in the course MS 421 Computer Laboratory*

MS 421 Computer Laboratory+ **(L0-T0-P2 –CH4 -CR 2)**

+ *Practical unit for the course MS 411 Computer Programming*

MS 414: Theory of Ordinary Differential Equations (L3 -T1 -P0 -CH4 -CR 4) Unit -1

Review of fundamentals of ODEs, Some basic mathematical models, direction fields, classification of differential equation, Solutions of some differential equation. 1st order nonlinear differential equation.

Existence and Uniqueness problem, Gronwall's inequality, Peanao existence theorem, Picard existence and uniqueness theorem, interval of definition.

Unit -2

Second order linear differential equation, General solution for homogeneous equation, superposition of solutions, Methods of solution for non-homogeneous problem: undetermined coefficients, variation of parameters. **Unit -3** nth order differential equation, system of equation, homogeneous system of equation, fundamental matrix, Abel-Liouvelle formula, System of non-homogeneous equations,

Stability of linear systems.

Unit -4

Theory of two point BVP, Greens function, Greens matrix, properties of greens functions, Adjoint and self adjoint BVP.

Unit -5

Strum-Liouvilles problem, Orthogonal functions, eigen values & eigen functions, Completeness of the Eigen functions.

Unit -6

Orthogonal trajectory of a system of curves on a surface solution of pfaffian differential equations in three variables.

Unit -7

Stability of linear and non-linear system: Classification of critical points, Lyanpunov stability.

Textbook(s)

1. Boyce, W. E. and DiPrima, R. C. *Elementary Differential Equation and Boundary Value Problems*, 7th Edition (John Wiley & Sons(Asia), 2001).
2. Ross, S. L. *Differential Equations*, 3rd edition (Wiley 1984).

Reference book(s)

1. Simmons, G. F. *Differential Equations with Applications and Historical Notes* (McGraw Hill, 1991).
2. Coddington, E. A. *An Introduction to Ordinary Differential Equations* (Prentice-Hall, 1974).
3. Farlow, S. J. *An Introduction to Differential Equations and Their Applications* (McGraw-Hill International Editions, 1994).

MS 416: Numerical Analysis [+] **(L3 -T1 -P0 –CH4 -CR 4)**

Unit-1

Definition and sources of errors, Propagation of errors, Error analysis, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors.

Unit-2

Solution of system of linear algebraic equations: Iterative methods- Jacobi, Gauss-Seidel, Successive over-relaxation (SOR), symmetric SOR (SSOR). Numerical solution of nonlinear simultaneous equations, Newton's method, General iteration method.

Unit-3

Review of interpolation, Hermite interpolation. Spline interpolation, B-splines. Special emphasis on cubic spline.

Unit-4

Approximation of function: The Weierstrass and Taylor theorem, Minimax and least square approximations, Orthogonal polynomials.

Unit-5

Numerical solution of algebraic and transcendental equations: Methods based on first and second degree equations, rate of convergence. Theory of one point iterative methods and its convergence analysis, multipoint iterative methods. Numerical evaluation of multiple roots.

Unit-6

Overview of Nwton-Cotes method. Composite integration. Gaussian quadrature, one point, two point and three point formulae. Orthogonal polynomials, Gauss-Legendre, GaussHermite and Gauss-Laguerre quadrature formulae. Romberg integration**.**

Unit-7

Solution of ordinary differential equations. Picard method, Euler method, backward Euler method, modified Euler method, Runge-Kutta class of methods.

Unit-8

Solving problems with C codes.

Textbook(s)

1. Atkinson, K.E. *Introduction to Numerical Analysis* (John Wiley, 1989)
2. Jain, M.K., Iyengar, S.R.K. and Jain R.K. *Numerical methods for Scientific and Engineering Computation*, 5th edition (New Age International (P) Ltd., New Delhi, 2006).

Reference book(s)

1. Sastry, S.S. *Introductory methods of Numerical Analysis* (Prentice Hall of India, New Delhi, 1977)
2. *Hilderbrand*, F. B. *Introduction to Numerical Analysis* (Tata McGraw Hill, New Delhi, 1974).
3. Conte, S. D., Boor, Carl de. *Elementary Numerical Analysis - An Algorithmic Approach*, 3rd Edition (McGraw Hill, 1980).

MS 421 Computer Laboratory+ (L0-T0-P2 –CH4 -CR 2)

[+] *Practical unit for the course MS 411 Computer Programming*

MS 424: Computer Laboratory+ **(L0 -T0 -P2 -CH4 -CR 2)**

+ *Practical unit for the course MI 302 Numerical Analysis+.*

MS 501: Classical Mechanics **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Momentum and kinetic energy, motion about a fixed point, Euler's equation, General equation of motion for a single particle and a system of N number of particles, General Solution.

Unit-2

Motion of a heavy sphere in a cylinder and a cone, motion under no force, Torque, Poinst's representation of motion. **Unit-3**

Lagrange's equation of motion for holonomic systems, Velocity dependent potential, conservation theorem and symmetric properties, Lagrange's multiplier for holonomic and nonholonomic systems, Lagrange's equation for impulsive motion.

Unit-4

Hamiltonian of a dynamical system, Hamilton's canonical equation of motion, Cyclic coordinate, The Routhian, Conservation of energy and momentum. **Unit-5**

Lagrange's method for small oscillation, Normal modes, Equations and examples.

Unit-6

Integral invariants of poincare, Lagrange's and Poisson's brackets and their properties, Equation of Motion and conserved quantities using Poisson's brackets, Infinitesimal contact transformation. **Unit-7**

Euler's equation of calculus of variations, Brachistochrone problem, extremes under constraints, Hamilton's principle for conservative and non-conservative system, Holonomic and non-holonomic system. **Unit-8**

Derivation of Lagrange's and Hamilton's equations from Hamilton's principle of least action, Hamilton Jacobi theory, Hamilton's Principal Function.

Textbook(s)

1. Goldstein, H. *Classical Mechanics*, 2nd edition (Narosa Publishing House, New Delhi, 2000).
2. Rana, N. C. & Joag ,P. C. *Classical Mechanics* (Tata-McGraw Hill, 1991).

Reference book(s)

1. Takwale, R. G. & Puranik, P. S. *Classical Mechanics* (Tata-McGraw Hill, 1979, 41st reprint, 2010).
2. Yung-Kuo, L. *Problems and Solutions on Mechanics* (World Scientific, 1994).
3. Calkin, M. G. *Lagrangian and Hamiltonian Mechanics* (World Scientific, 1996).
4. Landau, L. & Lifshitz, E.M. *Mechanics: Course of Theoretical Physics, Vol. 1*, 3rd edition (Pergamon Press, 1976).

MS 508: Mathematical Methods **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Calculus of variations: Linear functionals, minimal functional theorem, general variation of a functional, Euler-Lagrange equation. Variational problems with fixed boundaries. Sufficient conditions for extremum.

Unit-2

Integral equations: Linear integral equations of the first and second kind of Fredholm and Volterra type, solution by successive substitutions and successive approximations, solution of equations with separable kernels. Fredholm alternative.

Unit-3

Nonlinear programming: formulation of NLPP, General NLPP, Kuhn-Tucker condition. Saddle point and NLPP.

Graphical solutions of NLPP, quadratic programming. Wolfe's modified simplex method, Beale's method. **Unit-4**

Game theory: Two-person zero-sum games, maximum criterion, dominance rules, mixed strategies, mini-max theorem, solutions of 2x2 and 2xm games.

Textbook(s)

1. Watson G. N. *A Treatise on the Theory of Bessel Functions* (Cambridge University Press, 1944).
2. Brown J. W. and Churchill, R. *Fourier Series and Boundary Value Problems* (McGraw Hill, 1993).
3. Roach, G. F. *Green's Functions (Cambridge University Press*, 1995).
4. Swarup, K., *Gupta*, P.K., Mohan, M., *Operations Research*, (Sultan Chand & Sons, 2007).

Reference book(s)

1. Gupta, A, S. *Calculus of Variations with Applications* (Prentice Hall of India, New Delhi 2003).
2. Mikhlin, S. G. *Integral equations* (The MacMillan Company, New york, 1964).

MS 561 Stochastic Processes I **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1 Simple (one dimensional) random walk.

(To follow the chapter on simple random walk in Feller (1996) Vol. I) **Unit-2** Discrete Markov chains: transition probability matrix, classifications of states and chains.

Unit-3

Introduction to Poisson Processes. **Unit-4**

Introduction to Renewal processes.

Textbook(s)

1. Feller, W. *An Introduction to Probability Theory and its Applications*, Vol. I (Wiley, 1966).
2. Medhi,. J. *Stochastic Processes* (Wiley Eastern Ltd., New Delhi, 1994). **Reference book(s)**
1. Bhattacharya, R. and Waymire, E. C. *Stochastic processes with applications* (SIAM, 1990).

MS 565 Fuzzy Sets and Applications-I **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Fuzzy sets - basic definitions, α-level sets, convex fuzzy sets.

Unit-2

Basic operations on fuzzy sets, types of fuzzy sets.

Unit-3

Cartesian products, algebraic products, bounded sum and difference, t-norms and t-conorms. Fuzzy sets in contrast of probability theory.

Unit-4

The extension principle - the Zadeh's extension principle, image and inverse image of fuzzy sets.

Unit-5

Fuzzy numbers, elements of fuzzy arithmetic.

Unit-6

Fuzzy relations and fuzzy graphs, composition of fuzzy relations, min-max composition and its properties, fuzzy equivalence relations, fuzzy relational equations, fuzzy graphs.

Textbook(s)

1. Klir, G. J. and Yuan, B. *Fuzzy Sets and Fuzzy Logic : Theory and Applications*, (Prentice Hall of India, New Delhi, 1997)

Reference book(s)

1. Zimmermann, H. J. *Fuzzy set theory and its Applications* (Allied publishers Ltd., New Delhi, 1991).

MS 566 Fourier Analysis **(L3 -T1 -P0 -CH4 -CR 4)**

Prerequisite: MS 410 Unit 1:

Fourier series: Orthogonal systems, Trigonometric system, Orthogonal polynomials, Genesis of the Fourier series.

Unit 2:

Convergence of Fourier series: Fejer mean and Cesaro mean, Convergence of the Fourier series, Fejer theorem, Uniqueness and convergence, Approximate identity, Fourier series of continuous and smooth functions.

Unit 3:

L^2 theory of Fourier series: Inversion formula and the Parseval identity.

Unit 4:

Fourier transforms, the Schwartz space,Plancherel formula, Maximal function and distributions, Tempered distribution,, Fourier analysis and filters. Bessel functions.

Unit 5

Fourier analysis and complex function theory: Paley Wiener's theorem, Tauberian theorem, Dirichlet problem.,Classical Hardy spaces F and M. Reisz theorem.

Textbook(s)

1. Katznelson, Y. *An Introduction to Harmonic Analysis* (Dover, New York, 1976).

Reference book(s)

1. Dym, I.H. and Mc Kean, H.P. *Fourier Series and Integrals* (Academic Press, 1985).
2. Folland G. B. *Fourier Analysis and Applications* (Brooks/Cole Mathematics Series, 1972).
3. Korner, T. *Fourier Analysis* (Cambridge, 1989).
4. Rudin, W. *Functional Analysis* (Tata Mc. Graw Hill, 1974).
5. Elias M. S. and Shakarchi, R. *Fourier Analysis An Introduction (*Princeton University Press, Princeton, 2004).

MS 573 Analytic Number Theory **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Arithmetical functions and Dirichlet multiplication, averages of arithmetical functions.

Unit-2

Elementary theorems on the distribution of primes, the prime number theorem, Chebyshev's functions and their relations.

Unit-3

Dirichlet's theorem for primes of the form *4n-1* and *4n+1*, distribution of primes in arithmetic progressions.

Unit-4

Quadratic residues and quadratic reciprocity law, applications of the reciprocity law, Gauss sums.

Unit-5

Dirichlet series, Euler products, Riemann zeta function and Dirichlet *L*-functions. **Unit-6**

Introduction to partitions, geometric representation, generating functions, Euler's Pentagonal number theorem, Jacobi triple product identity, recursion formula for *p(n).*

Unit-7

Partition identities of Ramanujan.

Textbook(s)

1. Apostol, T. M. *Introduction to Analytic Number Theory*, Springer International Student Edition (Narosa Publishing House, New Delhi, 1993).
2. Hardy, G.H. and Wright, E. M. *An Introduction to the Theory of Numbers*, 4th Edition (Oxford University Press, 1960).

Reference book(s)

1. Niven, I. and Zuckerman, H. *An Introduction to the Theory of Numbers*, 5th Edition (Wiley Eastern, New Delhi, 2000).
2. Andrews, G.E. *Number Theory* (Hindustan Publishing Corporation, New Delhi, 1992).

MS 581 Stochastic Process –II **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Branching processes- Properties of generating functions of Branching processes, Probability of Extinction, Distribution of the total number of progeny.

Unit-2

Galton-Watson process. Introduction Brownian motion process.

Unit-3

Wiener process, first passage time distribution for Wiener process, Ornstein-Ulhenbech process.

Unit-4

Queueing systems, Single server queueing models (M/M/1/μ, M/M/1/k, M/M/μ/μ, etc.)

Textbook(s)

1. W. Feller *An Introduction to Probability Theory and its Applications*, II (Wiley, 1998).

2. Bhattacharyya, R. and Waymire, E. C. *Stochastic processes with applications* (SIAM, 1990). **Reference book(s)** 1. Medhi, J. *Stochastic Processes* (Wiley Eastern Ltd., New Delhi, 1994).

MS 588 Applied Matrix Theory **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Review of basic linear algebra.

Unit-2

Canonical factorization, Q-forms.

Unit-3

Courant-Fischer minmax & related theorems. Perron-Frobenius theory. Matrix-stability.

Unit-4

Inequalities, g-inverse (A^-, A^m, A^+).

Unit-5

Drect, iterative, projection and rotation methods for solving linear systems & eigenvalue problems.

Unit-6

Applications

Textbook(s)

1. Datta, K. B. *Matrix and Linear Algebra* (PHI, 1991).
2. Watkins, D. S. *Fundamentals of Matrix Computation* (Wiley, 1991).
3. Golub, G. H. and Loan, C. F. Van. *Matrix Computation (*John Hopkin U. Press, Baltimore, 1996.)

Reference book(s)

1. Stewart, G. W. *Introduction to Matrix Computations* (Academic Press, 1973.)

MS 591 Computational Fluid Dynamics (L3 -T1 -P0 -CH4 -CR 4)

Unit-1

Basic equations of Fluid Dynamics. Analytical Aspects of PDE. Iterative methods – Stationary Methods. Krylov subspace methods.

Unit-2

Stationary Convection diffusion equations, Non-stationary convection diffusion equations. Conservation laws. Incompressible plane flows, Stream function and vorticity equations, Conservative form and normalizing systems, Method for solving vorticity transport equation, Basic Conservative property.

Unit-3

Finite volume and finite difference methods. Convergence and stability analysis, Explicit and implicit methods, Stream function equation and boundary conditions, Solution for primitive variables. Finite volume method, Application to Euler equations, Upwind difference scheme, Viscous flow solutions, Total variation diminishing schemes, Godunov-type schemes.

Unit-4

Simple CFD Techniques, Lax-Wendroff Technique, Mac Cormack's Techniques, Staggered grid, SIMPLE Algorithm. Numerical Solutions of Navier-Stokes equations on collocated and on staggered grids.

Textbook(s)

1. Chung, T.J. *Computational fluid Dynamics* (Cambridge University Press, 2005).
2. Fletcher, C. A. J. *Computational Techniques for Fluid Dynamics, Volume 1 & 2*, (Springer Verlag, 1992).

Reference book(s)

1. Chow, C. Y. *Introduction to Computational Fluid Dynamics* (John Wiley, 1979).
2. Holt, M. *Numerical Methods in Fluid Mechanics* (Springer Verlag, 1977).
3. Wirz, H. J. and Smolderen, J. J. *Numerical Methods in Fluid Dynamics* (Hemisphere, 1978).
4. Anderson, J. D. *Computational Fluid Dynamics* (Mc-Graw Hill, 1995).
5. Anderson, D. A., Tannehill, J. C. and Pletcher, R. H. *Computational Fluid Dynamics and Heat Transfer* (McGraw Hill, 1984).

MS 599: Probability Theory **(L3 -T1 -P0 -CH4 -CR 4)**

Unit-1

Measurable space, Measure and its properties, finite and sigma-finite measures, Axiomatic definition of Probability, Measurable functions , definition of Random Variable. **Unit-2**

Measure induced by a measurable function, definition of Probability distribution and distribution function, properties of distribution function and classification of distributions.

Unit-3

Some basic theorems Integration theory(integration of measurable functions w. r. t. an arbitrary measure): Fatou's lemma , Monotone Convergence theorem, Dominated convergence Theorem. Definition of Mathematical Expectation of a random variable and its properties. Moments and moment inequalities.

Unit-4

Convergence of a sequence of random variables (Weak convergence or convergence in probability, almost sure convergence and convergence in Law). Borel-Cantelli-lemma, Weak and Strong law of large numbers, Central limit theorem.

Textbook(s)

1. Feller, W. *An Introduction to Probability Theory and its Applications*, Vol. II (Wiley, 1966).
2. Chow, Y. and Teicher, H. *Probability Theory , Independence, Interchangeability, Martingales,;* 3rd Edition (Springer, 1997).

Reference book(s)

1. Ash, R. B. *Probability and Measure Theory, Second Edition* (Harcourt/Academic Press, 2000).