R-912
13.8.2026

# UNIVERSITY OF CALCUTTA

## Notification No. CSR/92/2026

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 05.08.2026, approved the syllabus of 2-year (Four Semester) M.Sc. Course of Study in Applied Mathematics, under NEP guidelines, as laid down in the accompanying pamphlet.

The above syllabus shall take effect from the academic session 2026-2027 and onwards.

12.08.2026

Prof.(Dr.) Debasis Das
Registrar

SENATE HOUSE
Kolkata-700073
12.08.2026

# Department of Applied Mathematics

# University of Calcutta

# M.Sc. Syllabus and Curriculum Under NEP

# With effect from the Academic Session 2026-27

Two year PG Programme (after 3 years of UG programme) and One year PG Programme (after 4 years of UG programme)

| **PG 1st Year** | **Course ID** | **Name of the Course** | **Full Marks(End Sem Exam+ Internal Assessment)** | **Credit** |
|---|---|---|---|---|
| | | | | |
| Semester I | AMT411 | Analytical Mechanics | 50(40+10) | 3TH+1TU |
| | AMT412 | Abstract Algebra& Linear Algebra | 50(40+10) | 3TH+1TU |
| | AMT413 | Complex Analysis & Measure Theory | 50(40+10) | 3TH+1TU |
| | AMT414 | Ordinary Differential Equations & Partial Differential Equations | 50(40+10) | 3TH+1TU |
| | AMT415 | Generalized function, Integral Transform & Integral Equations | 50(40+10) | 3TH+1TU |
| **Total** | | | **250** | **20** |
| Semester II | AMT421 | Graph Theory & Discrete Mathematics | 50(40+10) | 3TH+1TU |
| | AMT422 | Electromagnetism, Special Theory of Relativity and Nonlinear Partial Differential Equations | 50(40+10) | 3TH+1TU |
| | AMT423 | Topology, Functional Analysis & Operator Theory | 50(40+10) | 3TH+1TU |
| | AMT424 | Optimization Techniques& Stochastic Process | 50(40+10) | 3TH+1TU |
| | AMT425 | Continuum Mechanics & Computational Methods I | 50(40+10) | 3TH+1TU |
| **Total** | | | **250** | **20** |

| PG 2nd Year | Course ID | Name of the Course | Full Marks (End Sem Exam+ Internal Assessment) | Credit |
|---|---|---|---|---|
| | | | | |
| Semester III | AMT511 | Research Methodology(including IKS) | 50(40+10) | 3TH+1TU |
| | AMT512 | Computational Methods II and Calculus of Variations | 50(40+10) | 3TH+1TU |
| | AMT513 | Machine Learning & Data Science | 50(40+10) | 3TH+1TU |
| | AMT514 | Martingale & Financial Mathematics | 50(40+10) | 3TH+1TU |
| | AMT515 | Research Paper I # | 50(40+10) | 3TH+1TU |
| **Total** | | | **250** | **20** |
| Semester IV | AMT521 | Computational Laboratory | 50(40+10) | 4P |
| | AMT522 | Research Paper II ## | 50(40+10) | 3TH+1TU |
| | AMT523 | Research Paper III ## | 50(40+10) | 3TH+1TU |
| | AMT524 | Elective Paper (UGC MOOCs* ) | 50 | 4 |
| | AMT525 | Dissertation | 50 | 4 |
| **Total** | | | **250** | **20** |

**Th-Theory; TU- Tutorial; P-Practical. IA- Internal Assessment. The marks of Internal assessment will be provided through continuous assessment/ home assignments/ mid semester examination or combination of any two depending on the subject matter of the modules/papers. The respective resource persons will record the process of marking internal assessment.**

***MOOCs: Massive Open Online Courses. A list will be provided by the Department in each year at the time of starting the session.**

**# A list of Research papers will be provided out of which students will choose his/her choices**

**## A list of Research papers will be provided out of which students will choose two papers. The department will guide which modules will be convenient with the earlier choice of Research paper I (subject to availability of resource persons). It may vary year to year.**

**The courses and curriculum of one year PG programme after completion of 4 year UG programme is same as that of PG Second year courses mentioned above, i.e., of Semester III and Semester IV courses and curriculum(the detailed will be provided very soon).**

# Detailed Syllabus

# M.Sc. First Year

## Module:-AMT411
## ANALYTICAL MECHANICS

### General Concepts:

Mechanics of a system of particles: Constraints- classification and examples; Virtual displacement, degrees of freedom, reactions due to the constraints and principle of virtual work; General equations of motion and Lagrange's First kind of equations. D'Alembert's principle; Generalized coordinates; Generalized forces; Canonically conjugate coordinates and momenta; Lagrangian; Lagrange's equations of motion; velocity dependent potential; Principle of energy; Rayleigh's dissipation function.

Configuration spaces, Integrals of motion; Action Integral; Hamilton's principle; Lagrange's equations by variational methods; Hamilton's principle for non-holonomic system; Symmetry properties and conservation laws; Noether's theorem. Ignorable/Cyclic coordinates; Routhian and Routhian equations of motion.

Legendre transformation; Phase spaces; Hamiltonian; Hamilton's equations from variational principle; Poincare-Cartan integral invariant; Principle of stationary action; Fermat's principle; Liouville's theorem. Canonical transformation; Generating function; Poisson Bracket; Equations of motion; Action-angle variables; Hamilton-Jacobi's equation; Hamilton's principal function; Hamilton's characteristics function; Action angle variables; Stability and integrable systems. Need for new mechanics.

**Rigid Dynamics:**

Kinematics of a rigid body. Euler angles. Caylay-Klein parameters. Euler's theorem, Chasles' theorem; Rotation Matrices; Finite and infinitesimal rotations. Rodrigues' formula for rotations;Homogeneous Transformation Matrices. Inertia tensor. Principal axis transformation. Euler equations of motion. Torque free motion. Tennis Racket Theorem; Motion of a free top about a fixed point.

Small oscillations about equilibrium. Normal coordinates. Oscillations under constraints. Stationary character of a normal mode.

### References:

1. H. Goldstein, Classical Mechanics, Narosa Publ., New Delhi, 1998.

2. N.C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw Hill, New Delhi, 2002.

3. E.T. Whittaker, A Treatise of Analytical Dynamics of Particles and Rigid Bodies, Cambridge Univ. Press, Cambridge, 1977.

4. F. Gantmacher, Lectures in Analytical Mechanics, Mir Publ., 1975.

5. T.W.B. Kibble and F.H. Berkshire, Classical Mechanics, 4th ed., Addison-Wesley Longman, 1996.
6. V.I. Arnold, Mathematical Methods of Classical Mechanics, 2nd ed., Springer-Verlag, 1997.
7. N.G. Chetaev, Theoretical Mechanics, Springer-Verlag, 1990.
8. M. Calkin, Lagrangian and Hamiltonian Mechanics, World Sci. Publ., Singapore, 1996.
9. J.L. Synge and B.A. Griffith, Principles of Mechanics, McGraw Hill, Singapore, 1970.
10. E.C.G. Sudarshan and N. Mukunda, Classical Dynamics: A Modern Perspectives, John Wiley & Sons, 1974.
11. J.R. Taylor, Classical Mechanics, University Science Books, California, 2005.
12. L.D. Landau and E.M. Lifshitz, Mechanics, 3rd ed., Pergamon Press, 1982.
13. A.K. Raychaudhuri, Classical Mechanics, A course of lectures, Oxford University Press, Calcutta, 1983.
14. Joseph S. Torok, Analytical Mechanics: With an Introduction to Dynamical Systems, John Wiley & Sons, 1999.
15. K.M. Lynch and F.C. Park, Modern Robotics Mechanics, Planning and Control, Cambridge Univ. Press, Cambridge, 2017.

## Module:-AMT412
## ABSTRACT & LINEAR ALGEBRA

### Group A: ABSTRACT ALGEBRA-[Full Marks including IA: 20]

- Group Actions, Permutation Representation of group action, Orbit, Stabilizer, Applications of group actions, Extended Cayley's theorem, Index Theorem, Cauchy-Frobenius theorem.
- Groups acting on themselves by conjugation, Conjugacy classes, Class equation and consequences, conjugacy in $S_n$; Cauchy's theorem on finite groups, $p$-group, Centre of $p$-groups; Sylow's theorems; Applications of Sylow's theorems: Simple groups, Groups of order $p^n$ $(n > 1), pq, p^2q, p^2q^2$ $(p, q$ are distinct primes), $A_n$ $(for\ n \geq 5)$.
- Finite Abelian group, Fundamental theorem of finite Abelian groups, classification of all non-isomorphic Abelian groups of a given finite order, finite generated free Abelian groups.
- Group representations, Reducible and Irreducible representations, Unitary representation, Schur's lemma, Orthogonality theorem (statement only), Maschke's Theorem (statement only); Characters of a representation and its properties.
- Field Extensions, Algebraic and Transcendental extensions, Degree of extension, Finite extension; Splitting Field, Krönekar Theorem, Existence of Splitting Field for any non-constant polynomial over a field, Existence of Algebraically closed field, Algebraic Closure of a field; Perfect Field, Artin's theorem(statement only); Finite fields, Separable and Inseparable extension, Mobius Function, n-th Roots of Unity forms a cyclic group isomorphic to $(\mathbb{Z}/n\mathbb{Z}, +)$.

## Group B: LINEAR ALGEBRA-[Full Marks including IA: 30]

Solutions of system of linear equations; Four fundamental subspaces; Row space; column space, existence and uniqueness of solutions to Ax=b; solution of underdetermined and over determined system of linear equations.

Orthogonal Complements and Projections:Projection Operators; Dual Spaces; Adjoints; Normed Vector Spaces; Linear Operators on Inner Product Spaces; Self-Adjoint and Normal Operators; Geometry in Inner Product Spaces; Orthonormal Sets and the Gram–Schmidt Process; Spectral Theorems; Normal Operators on Real Inner Product Spaces; Unitary and Orthogonal Operators.

Matrix Approximation Problems: The Closest Hermitian Matrix; The closest unitary matrix;Schur triangularization theorem; Some Density Theorems (Invertible matrices are dense, Matrices with distinct eigenvalues are dense, Diagonalizable matrices are dense etc.)

Matrix Decompositions: The QR and the Polar Decompositions; Cholesky Decomposition; Eigenvalue Decomposition; Singular Value decompositions (with Geometric interpretation); Singular values and vectors; Low rank approximations; Best rank-k approximation; Eckart-Young Theorem; Principle component analysis(PCA); Canonical correlation clarification by Singular value decomposition; Pseudo inverses; solutions of constrained least square solutions; Applications in image compression, feature extraction.

Theory of a Single Linear Operator
Invariant Subspaces of an Operator, Cyclic Operators; Canonical Forms; The Rational and Jordan Forms; Cyclic Subspaces and Annihilators. Cyclic Decompositions and the Rational Form; The Jordan Form.

Majorization and Doubly Stochastic Matrices: Majorization; Doubly stochastic matrices; T-transforms; Majorization and doubly stochastic matrices; The Schur–Horn theorem.

Applications in Machine Learning and Robotics.

Error Correcting Codes: Linear codes and their decoding; Non-binary codes; Elementary properties of linear codes; Correctable errors; Decoding of linear codes; Linear codes, generator and parity check matrices; Hamming Codes.

### References:


1. D.S. Malik, J. M. Mordeson and M.K. Sen, Fundamentals of Abstract Algebra; McGraw Hill, 1997.
2. M. Artin, Algebra; Prentice Hall, 1994.
3. W. Fulton and J. Harris, Representation Theory: A First Course; Springer-Verlag New York, 1991.
4. D. S. Dummit and R. M. Foote; Abstract Algebra, 3rd Edition; John Wiley & Sons, 2003.
5. Pavel Etingof et. al., Introduction to representation theory, MIT Mathematics, American Mathematical Society,2011.

6. S. Lovett, Abstract Algebra: Structures and Applications; CRC Press, 2016.
7. J.P. Escofier, Galois Theory; Springer-Verlag New York, 2001.
8. J. W. Lawrence and F. A. Zorzitto, Abstract Algebra: A Comprehensive Introduction, Cambridge Mathematical Press, 2021.
9. J. McCleary, Actions of Groups: A Second Course in Algebra: Cambridge, Cambridge University Press, 2023.
10. László Fuchs, Abelian Groups, Springer International Publishing, Switzerland 2015.
11. A.R. Rao and P. Bhimasankaram, Linear Algebra, Hindustan Book Agency, 2000.
12. K. Hoffman and R. Kunze, Linear Algebra, Prentice Hall of India, 2003.
13. R.A. Horn and C.R. Johnson, Matrix Analysis, Cambridge University Press, 2012.
14. R. Bhatia, Matrix Analysis, Springer-Verlag, New-York, 1997.
15. S. Roman, Advanced Linear Algebra, Springer, 2007.
16. P.R. Halmos, Finite Dimensional Vector Spaces, Springer-Verlag, 1987.
17. G. Strang, Introduction to Linear Algebra, Wellesley Cambridge Press, 2003.
18. G. E. Shilov, Linear algebra, Dover Publ., 1977.
19. H. Dym, Linear Algebra in Action, American Mathematical Soc., 2006.
20. T.B. Blyth and E.F. Robertson, Further Linear Algebra, Springer, 2001.
21. F. Zhang, Matrix Theory, 2nd Ed., Springer, 2011.

## Module:-AMT413
## COMPLEX ANALYSIS & MEASURE THEORY

### Group A: Complex Analysis-[Full Marks including IA: 30]

Analytic functions, Cauchy-Riemann equation, Zeros of analytic functions, multiple valued functions, Branch cuts, Concept of Riemann sheet.

Curves in the complex plane, Complex integration, Jordon's Lemma, Cauchy's theorem, Morera's theorem, Cauchy integral formula, Cauchy integral formula for derivatives, Maximum modulus principle, Minimum modulus principle, Open mapping theorem, Schwarz lemma, Liouville's theorem, Fundamental theorem of algebra.

Series. Uniform convergence, Properties of uniformly convergent series, Power series, Taylor series, Uniqueness theorem, Analytic continuation, Laurent series, Singularities, Classification of singularities. Cauchy's residue theorem. Evaluation of some integrals, Residue theorem for extended complex plane, Argument principle, Rouche's theorem. Hurwitz theorem.

Conformal mapping, Mobius transformation and its properties.

### Group-B: Measure Theory-[Full Marks including IA: 20]

Riemann-Stieltjes integrals; Simple properties, integrators. Sigma algebra, General measures and measurability. Outer measure, Caratheodory extension theorem. Lebesgue measure. Completeness, measurable functions and their properties. Almost everywhere properties. General integrals and theory of Lebesgue integration; their properties. Monotone convergence theorem. Beppo Levi's theorem. Fatou's lemma, Lebesgue dominated convergence theorem. Relation with Riemann integrals. Almost everywhere convergence. Lp spaces, Vitali's theorem. Signed measure, Hahn and Jordan decomposition. Differentiation of integrals. Absolute continuity, Radon Nikodym theorem. Product measures and Fubini's theorem.

## References:


1. R. P. Agarwal, K. Perera and S. Pinelas; An Introduction To Complex Analysis, Springer-Verlag, 2011.
2. L. V. Ahlfors, Complex Analysis (Third Edition), McGraw-Hill, New York, 1979.
3. J. Bak and D. J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
4. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 8th Ed., McGraw–Hill International Edition. 2009.
5. J. B. Conway, Functions of One Complex Variable; Narosa Publishing, New Delhi, 1973.
6. T. W. Gamelin, Complex Analysis; Springer International Edition, 2001.
7. R. E. Greene & S. G. Krantz, Function Theory of One Complex Variable, Third Edition, Graduate Studies in Mathematics. Volume 40, AMS, 2006.
8. S. Lang, Complex Analysis (Fourth edition), Springer-Verlag, 1999.
9. R. Narasimhan, Complex Analysis in one variable; Birkhauser, Boston, 1984.
10. S. Ponnusamy, Foundations of Complex Analysis, second edition; Narosa Publishing, New Delhi, 2005.
11. H. A. Priestly, Introduction to complex analysis, 2nd Ed., Oxford University Press, 2003.
12. E. M. Stein and R. Shakarchi, Complex Analysis, Princeton University Press, Princeton, New Jersey, 2003.
13. D. G. Zill & P. D. Shanahan, A First Course in Complex Analysis, Jones & Bartlett Publishers Inc., 2003.
14. H.L. Royden, Real Analysis, 3rd ed., Macmillan Publishing Co., Inc., New York, 1989.
15. E.C. Titchmarsh, Theory of Functions, Clarendon Press, 1932.
16. I.P. Natanson, Theory of Functions of a Real Variable, Vols. I & II, Akademie-Verlag, Berlin, 1981.
17. S. Kumaresan, and D. Sheetal. A Course in Lebesgue Measure and Integration. Techno World, 2026.
18. G. De Barra, Measure Theory and Integration, 2nd ed., Woodhead Publishing, 2003.
19. M.E. Munroe, Measure and Integration, Addison Wesley, 1953.
20. A.E. Taylor, General Theory of Functions and Integration, Blaisdell, 1965.
21. S. Saks, Theory of Integrals, Warsaw, 1937.

22. S.K. Berberian, Measure and Integration, McMillan, New York, 1965.
23. J.C. Burkill, The Lebesgue Integral, Cambridge University Press, 1961.
24. P.R. Halmos, Measure Theory, Narosa Publ., Student ed., 1981.
25. Donald L. Cohn, Measure Theory, Birkhauser, Boston, 1980.

## Module:-AMT414
## ORDINARY DIFFERENTIAL EQUATION &
## PARTIAL DIFFERENTIAL EQUATION

### Group A: Ordinary Differential Equation - [Full Marks including IA: 30]

• First Order Equations (Initial Value Problems): Characterization of continuable solutions; Existence and Classification of saturated solutions; continuous dependence on initial data; Well-posed problems.

• Qualitative Analysis of One-dimensional Continuous Systems: Autonomous first order differential equations –Equilibrium points (or steady states or fixed points or stationary points), Lyapunov Stability and asymptotic stability of a steady state; linear stability analysis.

• Systems of Differential Equations: Types of linear systems, Differential Operators and an Operator Method, Basic Theory of Linear Systems in Normal Form; Fundamental Matrix, Homogeneous Linear Systems with Constant Coefficients: The Matrix Method for Homogeneous Linear Systems with Constant Coefficients: Two Equations in Two Unknown Functions, Planar linear autonomous systems: Equilibrium points, Interpretation of the phase plane and phase portraits. Planar Nonlinear systems: Equilibrium points and their stability by linearization.

• Series Solution and Special Functions: Ordinary point and singular point. Types of singularity. Series solution of a second order differential equation, Frobeneous method, Legendre equation and Legendre function, Bessel equation and Bessel functions, orthogonality conditions.
• Qualitative Properties of Solutions of second order linear homogeneous equations: Sturm separation theorem, Strum Comparison theorem.

Boundary Value Problems: Adjoint forms, Self-adjoint operator, self-adjointisation; Lagrange identity, Greens identity, Two point boundary value problem, Fundamental solutions, Green's functions; Construction of Green's functions; Sturm-Liouville problems; properties of the Sturm-Liouville Boundary Value Problem (SL-BVP); A self-adjoint periodic SL-BVP has an infinite sequence of real eigenvalues. Eigenvalues and Eigen functions of the Schrodinger equation for quantum particle freely moving on a circle.

Concept of nonhomogeneous equations; nonhomogeneousboundary conditions.

## Group B: Partial Differential Equation - [Full Marks including IA: 20]

• $1^{st}$ order PDE : The method of characteristics; transversality condition, no solution; infinitely many solutions; the existence and uniqueness theorem, well-posedness; classical and weak solutions of linear PDE.

- Classification of second order linear partial differential equations, Reduction to Canonical form and general solution, Characteristic curves of second order equation.

• Hyperbolic Equations: The one-dimensional and higher dimensional Wave Equation; The Cauchy problem and d'Alembert's solution; Physical interpretation of the solution. Solution of wave equation by the method of Separation of variables in Cartesian, spherical and cylindrical coordinates. Domain of Dependence and region of influence; Solution by the method of Integral transform.

• Parabolic equations: The Heat equation: homogeneous and non-homogeneous boundary conditions; Solution of heat equation by the method of Separation of variables in Cartesian coordinates; Solution using integral transform.

• Elliptic equations: Laplace and Poisson equations

Laplace and Poisson equation, Dirichlet and Neumann boundary conditions, Interior and exterior boundary value problems. Separation of variables in Cartesian and cylindrical coordinates with simple examples, Poisson's formula. Maximum principle, Applications of Maximum principle to uniqueness and stability of solution; Green's functions and integral representations.

## References:


1. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations, John Wiley & Sons, 7th Edition, 2000.
2. E. A. Coddington and N. Levison, Theory of Ordinary Differential Equations, Tata McGraw Hill, 1955.
3. E. L. Ince, Ordinary Differential Equations, Dover, 1956.
4. S. L. Ross, Differential Equations, John Wiley and Sons, 3rd edition, 1984.
5. G. Simmons, Differential Equations with Applications and Historical Notes, McGraw Hill Education, $2^{nd}$edition, 2017.
6. L. C. Evans, Partial Differential Equations, Second Edition, American Mathematical Society, 2014.
7. T. Myint-U and L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, Birkhauser, 4th edition, 2007.
8. K. S. Rao, Introduction to partial differential equations, Prentice Hall, New Delhi, 1997.
9. I. N. Sneddon, Elements of partial differential equations, McGraw Hill, 1986.
10. Walter A. Struss, Partial Differential Equations: An Introduction, John Wiley & Sons, $2^{nd}$ Edition, 2007
11. U. Ghosh, N. Sarkar, B. Paul, Green's function, Laplace and Fourier Transform, Techno World, $1^{st}$ Edition, 2026.
12. S. J. Farlow, Partial Differential Equations for Scientists and Engineers, John *Wiley* & Sons, 1st Edition, 1982.

13. Y. Pinchover and J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press, 1st Edition, 2005.

## Module:-AMT415

**GENERALISED FUNCTIONS, INTEGRAL TRANSFORMS & INTEGRAL EQUATIONS**

### Group A: Generalised Functions and Integral Transforms [Full Marks including IA: 35]

Introduction and notations, Test functions, Linear functional, Space of Generalised functions, Completeness of Generalised functions, Support of a Generalised Function, Regular Generalised functions, Singular Generalised Function, The Dirac Delta function, Support of a Delta function, and Delta sequences. Changeof variables in Generalised function, Multiplication of Generalised Function, Sochozki formula, Derivative of a Generalised function, Anti-derivative of a Generalised Function and examples.

Fourier Transform: Definition and Algebraic properties of Fourier transform, Convolution, Translation, Modulation, Analytical properties of Fourier transforms, Transform of derivatives and derivatives of transform, Perseval formula, Inversion theorem, Application to solving ordinary differential equations.
Laplace Transforms: Definition and Algebraic properties of Laplace transform, Transform of derivatives and derivatives of transform, Convolution, The inversion theorem and its application to find inverse of Laplace Transform, Application to solving ordinary differential equations.
The Hankel transform: Elementary properties; Inversion theorem; transform of derivatives of functions; Perseval relation; Relation between Fourier and Hankel transform; use of Hankel transform in the solution of PDE.
The Mellin transform: Definition; properties and evaluation of transforms; Convolution theorem for Mellin transforms; applications to integral equations.
The Z-Transform: Properties of the region convergence of the Z-transform. Inverse Z-transform for discrete-time systems and signals, Signal processing and linear system.

### Group B: Integral Equations- [Full Marks including IA: 15]

Reduction of boundary value problem of an ordinary differential equation to an integral equation. Fredholm equation: Solution by the method of successive approximation. Neumann series. Existence and uniqueness of the solution of Fredholm equation. Equations with degenerate kernel. Eigen values and eigen solutions. Volterra equation: Solution by the method of iterated kernel, existence and uniqueness of solution. Solution of Abel equation. Solution of Volterra equation of convolution type by Laplace transform.

**References:**

1. Peter K. F. Kuhfittig, Introduction to the Laplace Transform, Plenum Press, N.Y., 1980.
2. D. Loknath, Integral Transforms and their Application, C. R. C. Press, 1995.
3. I. N. Sneddon, Fourier Transform, McGraw-Hill, 1951.
4. E. J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.
5. R. F. Hoskins, Generalized functions, Horwood, Chichester and New York, 1979.
6. D. S. Jones, Generalized Functions, Cambridge University Press, 1982.
7. R. P. Kanwal, Generalized Functions: Theory and Technique, Birkhauser, New York, 1998.
8. V. S. Vladimirov, Generalised Functions in Physics, MIR Publishers, Moscow,1979.
9. H. Hochstadt, Integral equations, Wiley-Interscience, 1989.
10. W. Pogorzclski, Integral Equations and Their Application, Vol. I, Pergamon Press, Oxford.
11. D. Porter and D. S. G. Stirling, Integral Equations, Cambridge University Press, 2004.
12. F. G. Tricomi, Integral Equations, Dover, 1985.
13. A. Wazwaz, A first course in integral equations, World Scientific, 1997.

## Module:-AMT421

## GRAPH THEORY & DISCRETE MATHEMATICS

### Group A:Graph Theory- [Full Marks including IA: 30]

- Historical background, Definition of Graph and Multigraph; Degree of a vertex, degree sequences, Havel-Hakimi Theorem.
- Walks, paths, trails and cycles; subgraphs, spanning subgraphs and induced subgraphs, connected graph, components of a disconnected graph; complete graph, complete bipartite graphs, complement of a graph, self-complementary graphs; Cartesian product of two graphs.
- Cut vertex, Bridge, Cut-set; Vertex connectivity, Edge connectivity, Relation between vertex connectivity, edge connectivity and minimum degree.
- Eccentricity, Distance, Centre, Radius, Diameter, Relation between Radius and diameter; Distance in weighted graph, Dijkstra’s Shortest Path Algorithm.
- Seven bridges problem, Eulerian graphs, Theorems on existence of Euler paths and circuits, Unicursal line and Eulerization; Hamiltonian graphs. Sufficient conditions of Dirac and Ore for a graph to be Hamiltonian; Applications: Chinese postman problem, Traveling Salesman Problem, Icosian game, Instant-Insanity game, Seating arrangement problem, DNA sequencing and others.
- Trees; Spanning Tree of a connected graph, Minimal Spanning Tree; Kruskal’s and Prim’s Algorithm to find Minimal Spanning Tree in a weighted graph, Rooted Binary tree, Binary search trees; Applications on Network Design, Hierarchical system, Decision trees in machine learning.

- Definition of planar graphs, Crossing Number, Kuratowski's two graphs, Euler's theorem on planar graph; detection of planarity, Kuratowski's theorem (statement only). Homeomorphic graph, Geometric Dual of a planar graph. Applications: Utility problem, Regular Polyhedra, Circuit board design, Geographic Information System, Network analysis.
- Vertex colouring of graphs, Chromatic number of graphs and its properties, Greedy Colouring algorithm, Four colour theorem (Statement only), Applications.
- Independence and Matching of Bipartite graphs, Perfect Matching. Applications: Assignment problem.
- Directed graphs (Digraphs), digraphs and binary relations, strongly connected digraphs, Acyclic digraphs, Orientation of a graph, Strong orientation, Tournaments, Score, Dominance, Reducible and Irreducible Tournaments, Reachability digraph, Directed Euler Walk, Bellman-Ford Algorithm to find shortest path in a digraph.
- Adjacency matrices and Incidence matrices of graphs and digraphs and their properties, Path matrices of a digraph, Application in Data Structure.

## Group B: Discrete Mathematics- [Full Marks including IA: 20]

Pigeon Hole Principle; Dirichlet's Application; Generalized Pigeon Hole Principle and Problems; Another form of Pigeon hole Principle; Strong form of Pigeon Hole Principle; Erd¨os-Szekeres: Monotone Sequences; Infinite generalizations of the PHP; Dilworth's Theorem; Mantel's Theorem.
Ramsey Theory: Ramsey Theorem Weak Form; Ramsey Theorem Strong Form; Applications of the Ramsey Theorem; Van der Waerden Theorem.

Lattice: Partially ordered sets, Lattices, Distributive and complete lattices, Dilworth's theorem on POSET, Applications.
Boolean Algebra: Boolean Algebra as Lattices. Various Boolean Identities 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). The Karnaugh Map method; Quine-McCluskey method; Don't care conditions.

Automata and Languages: Regular Languages; Finite Automata; Formal definition of a finite automaton; Examples of finite automata; Formal definition of computation; Designing finite automata; The regular operations; Non determinism; Formal definition of a nondeterministic finite automaton; Equivalence of NFAs and DFAs; Closure under the regular operations; Regular Expressions; Formal definition of a regular expression; Equivalence with finite automata; Nonregular Languages; The pumping lemma for regular languages.

## References:


1. W.D. Wallis, A Beginner's Guide to Graph Theory; Second Ed., Birkhauser Boston, 2007.
2. N.S. Deo, Graph Theory with Application to Engineering and Computer Science, Prentice Hall of India, 1994.

3. J. Clark and D. A. Holton, A First Look at Graph Theory, World Scientific, New Jersey, 1991.
4. B. Bollobas, “Modern Graph Theory”, Springer, 1998.
5. M. v. Steen, “Graph Theory and Complex Networks: An Introduction”, 2010.
6. V. Zverovich, “Modern Applications of Graph Theory”, Oxford University Publication, Oxford, 2021.
7. R. Diestel, “Graph Theory”, 6th Ed., Springer, 2024.
8. J.A. Bondy and U.S.R. Murty, Graph Theory and Applications, Elsevier North-Holland, 1976.
9. F. Harary, Graph Theory, Addison-Wesley, 1969.
10. J.L. Gross and J. Yellen, Graph Theory and its applications, CRC Press, 2005.
11. D.S. Malik and M.K. Sen; Discrete mathematical structures: theory and applications; Thomson, 2004.
12. D. West, “Introduction of Graph Theory”, Prentice Hall, 1996.
13. I.M.Copi, Symbolic Logic, Prentice Hall of India, 1979.
14. K.H. Rosen, Discrete Mathematics and its Applications, Tata McGraw Hill,7th Ed.,2012.
15. C.L. Liu, Elements of Discrete Mathematics, McGraw Hill, 1985.
16. V.K. Balakrishnan, Introductory Discrete Mathematics, Dover Publications. Inc. Newyork, 1996.
17. J. Gallier, Discrete Mathematics, Springer, 2011.
18. Brualdi, Introductory Combinatorics, Pearson Education. Inc, 2008.
19. J.H.Van Lint & R.M.Wilson, A Course in Combinatorics, Cambridge University Press, 2001.
20. D.D. Givone, Introduction to Switching Circuit Theory, McGraw Hill, 1996.
21. Peter J. Cameron, Combinatorics: Topics, Techniques, Algorithms, Cambridge University Press, 1994.
22. Richard P. Stanley, Enumerative Combinatorics: Volume 1 (Cambridge Studies in Advanced Mathematics, Series Number 49).
23. John E. Hopcroft, Rajeev Motwani, and Jeffrey D. Ullman, Introduction to Automata Theory, Languages, and Computation, Pearson, 2006.
24. Michael Sipser, Introduction to the Theory of Computation, Thomson Course Technology, 2006.

## Module:-AMT422

## ELECTROMAGNETISM, SPECIAL THEORY OF RELATIVITY AND NONLINEAR PARTIAL DIFFERENTIAL EQUATION

### Group A: Electromagnetism and Special Theory of Relativity- [Full Marks including IA: 35]

Coulomb’s law; Electric field; Gauss’s Law; Dielectric media; Electrostatic potential; Electric dipole; Multipole expansion; Point Charges and the Delta-Function; Poisson’s equation; Laplace equation; Fundamental solutions of Laplace and Poisson equation, Energy of the electrostatic field;. Green's reciprocity theorem; Electrostatic boundary conditions; Green's reciprocity theorem; The Lorentz force and magnetic field; Ampere's circuital law; Helmholtz's theorem; Vector potential. Magnetic dipole; Biot-Savart law; Magnetostatic boundary conditions; Conservation of charge: Equation of Continuity; Electromagnetic Induction; Faraday's law; Generalization of Ampere's law; Displacement current; Energy in the Electromagnetic Field; Poynting vector; Electromagnetic potentials; The Lagrange Function for a Charged Particle in an Electromagnetic Field; Electromagnetic wave equations; Gauge transformations; Coulomb and Lorentz gauges; Plane electromagnetic waves (potential formulation); Concept of Advanced and Retarded Potentials.

Galilean Transformations; Inertial frame; Michelson-Morley experiment; Special Theory of Relativity: Einstein's Postulates; Lorentz transformations (LT); Simultaneity; Time-dilation and Lorentz contraction; Velocity, Momentum, and Energy in Relativity; Constancy of speed of light; Concept of Minkowski space time; Covariant and Contravariant Vectors; Metric tensor; Minkowski length; Proper Time, Twin Paradox; LT through Minkowski space time; Space like and Time like intervals; Four Vectors in Electrodynamics; Electromagnetic Field Tensors; Covariant forms of equation of continuity and Maxwell equations; Lagrangian Formulation of motion of a Charged Particle in a relativistic Electromagnetic Field; Lagrangian Formulation of the relativistic Field Equations

## Group B: Nonlinear Partial Differential Equation- [Full Marks including IA: 15]

Concept of Phase velocity and Group velocity; Dispersive and dissipative wave; Dispersion Relation; First-Order Equations and Characteristics; Concept of nonlinearity; Wave breaking; Concept of discontinuous shock; Nonlinear equations; Conservation Law; Traveling wave solutions of Korteweg-de Vries equation and Burgers' equation; Concept of solitary wave, Soliton and continuous shock.

## References:


1. Mathematical Theory of Electricity and Magnetism: J.H. Jeans (Cambridge University Press,1957).
2. Electromagnetic Theory: V. C. A. Ferraro (Read Books, 2010)
3. Introduction to Electrodynamics: D. J. Griffiths (Prentice Hall, New Delhi,2000).
4. Introduction to Electromagnetic Theory: A Modern Perspective: Tai L. Chow (Jones and Bartlett, 2012).
5. Classical Electromagnetic Radiation: Mark A. Heald and Jerry B. Marion (Saunders College Publishing, 1995).
6. Maxwell's equations and the principles of electromagnetism: R.Fitzpatrick (Infinity Science Press LLC, 2008).
7. Special Relativity and Classical Field Theory: Leonard Susskind and ArtFriedman (Penguin, 2018).
8. Introduction to Special relativity: Robert Resnick (Wiley Student Edition, 2007).
9. Wave Motion: J. Billingham and A. C. King (Cambridge University Press, 2000).
10. Linear and Nonlinear Waves: G. B. Whitham (John-Wiley & Sons, 1974).

11. Non-Linear Waves in Dispersive Media: V. I. Karpman (Pergamon, 2016).
12. Nonlinear Waves in One-dimensional Dispersive Systems: P. L. Bhatnagar (Oxford University Press, 1980).
13. S. H. Strogatz, Nonlinear Dynamics and Chaos, Levant Books, Kolkata; 1st Indian edition, 2007.

## Module:-AMT423

## TOPOLOGY,FUNCTIONAL ANALYSIS & OPERATOR THEORY

Set theory, countable-uncountable sets, Zorn's Lemma, Well-ordering principle, the Axiom of Choice and Continuum hypothesis.
Topological spaces: Elementary concepts and examples, Kuratowski closure operator and neighbourhood systems; continuity, convergence, homeomorphism. Open bases and open subbases. Weak topologies. Order topologies, Subspaces, Product Spaces, Quotient spaces. Denseness, Separable spaces. First and Second countability,
Compactness, Tychonoff's theorem. Separation axioms, $T_i$ – spaces, Hausdorff, regular completely regular, normal spaces, salient features; Urysohn's Lemma and Tietze extension Theorem (statements only). Metrizability and Urysohn's Metrization Theorem(statement only). Connectedness, Connected Subspaces of Real Line, Components, totally disconnected spaces, Local and Path connectedness. Revision of characterisation of different compactness ideas in metric spaces, totally boundedness and equivalence theorem with compact metric space. Ascoli-Arzela's theorem.

Linear spaces: concept of basis in finite and infinite dimensional spaces; Linear topological spaces, semi norm, norm; Normed linear spaces, Banach spaces.
Linear functionals: Dual spaces, reflexive property.
Hilbert spaces, Orthogonality in Hilbert spaces and related theorems (Orthogonal Projection Theorem; Best Approximation; Generalized Fourier Series; Bessel's Inequality; Complete Orthonormal set; Perseval's Theorem). Hahn-Banach extension theorem, Representation of linear functionals on Hilbert spaces (Riesz-representation theorem), strong and weak convergences of a sequence of elements and of a sequence of functionals. Weak topologies in Banach spaces. Banach-Alaoglu theorem. Locally convex spaces, Krein-Milman's theorem
Linear operators: Linear operators in normed linear spaces, uniform and point wise convergence of operators; Banach-Steinhaus theorem. Uniform boundedness theorem. Open mapping theorem. Bounded inverse theorem. Closed linear operators, Closed graph theorem, Completely continuous operators and their properties. Adjoint operator, Self-adjoint operators; Normal and Unitary operators; Positive operators; Compact symmetric operator; Hilbert-Schmidt theorem, Eigenvalues and their properties. Resolvent and spectrum; Spectral theorem for bounded normal operators. Linear integral operator, Fredholm and Volterra type. Fredholm alternative.

## References:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, Singapore, 1963.
2. J.R. Munkres, Topology, A First Course, Prentice-Hall of India Pvt. Ltd., New Delhi, 2000.
3. H.L. Royden, Real Analysis, 4th ed., Macmillan Pub. Co., New York, 1993.
4. J.L. Kelley, General Topology, Von Nostrand, New York, 1995.
5. J. Dugundji, Topology, Allyn and Bacon, 1966 (Reprinted by PHI, India).
6. N. Bourbaki, General Topology Part-I, Addison Wesley, Reading, 1966.
7. G. Cain, Introduction to General Topology, Addison Wesley, Reading, 1994.
8. R. Engelking, General Topology, Polish Scientific Publishers, Warsaw, 1977.
9. M. J. Mansfield, Introduction to Topology, D-van Nostrand Co. Inc, Princeton, 1963.
10. B. Mendelson, Introduction to Topology, Allyn and BeconInc, Boston, 1962.
11. W. J. Pervin, Foundations of General Topology, Academic Press, N.Y., 1964.
12. L. Steen and J. Seebach, Counterexamples in Topology, Holt, Rinechart and Winston, N.Y., 1970.
13. W. J. Thron, Topological Structures, Holt, Rinehart and Winston, N.Y., 1966.
14. Stephen Willard, General Topology; Addison-Wesley, Reading, 1970.
15. W. Rudin, Functional Analysis, Tata McGraw Hill, New Delhi, 1992.
16. M. Reed and B. Simon, Functional Analysis, Academic Press, Inc., London, 1980.
17. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
18. K. Yosida, Functional Analysis, Springer Verlag, 1995.
19. N. Dunford and J.T. Schwartz, Linear Operators, 3 Volumes, Interscinece/ Wiley, New York, 1958-1971.
20. Ola Bratteli and D.W. Robinson, Operator Algebra and Quantum Statistical Mechanics 1, Springer-Verlag, New York, 1979.
21. A.N. Kolmogorov and S.V. Fomin, Elements of the Theory of Functions and Functional Analysis, 2 Vols., Graylock, Rochester, 1957 & 1961.
22. R.V. Kadison and J.R. Ringrose, Fundamentals of the theory of operator algebras, Vol. I & Vol. II, American Mathematical Society, 1997.
23. Bachman and Narici, Functional Analysis, Academic Press, 1966.
24. John B. Conway, A Course in Functional Analysis, Springer, 1990.
25. S. Kumaresan, D. Sukumar, Functional Analysis; Narosa Publishing House, 2024.
26. James C. Robinson, An Introduction to Functional Analysis, Cambridge Univ. Press, Cambridge, 2020.

# Module:-AMT424
# OPTIMIZATION TECHNIQUES & STOCHASTIC PROCESS

## Group A: Optimization Techniques - [Full Marks including IA: 35]

Integer Programming: Integer programming models; Branch-and-Bound method; Gomory's Cutting plane method.

Network Optimization: Graph representations, Max-flow-min-cut theorem(Statement only), Maximum flow algorithms (Ford–Fulkerson, Edmonds–Karp), Minimum cost flow problems, Analysis of a project thorough network diagram, Network scheduling by Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT), Float time, Slack time.

Queuing Theory: Poisson process and Exponential distribution, Markovian property of exponential distribution, Birth-Death Process, Single channel exponential queuing models, steady state solutions for $M/M/1/\infty/FCFS$ model, Measure of effectiveness, Waiting time distributions, Finite system capacity queues; Applications in communication and service systems.

Inventory Models: Concept of Economic Order Quantity (EOQ) and Economic Production Quantity (EPQ), Problem of EOQ with constant demand, Problem of EOQ with variable demand rate, Problem of EOQ with finite rate of replenishment, Problem of EOQ with shortages, Problem of EOQ with Quantity discounts, Safety stocks, Probabilistic Inventory Models with Continuous Review, News vendor model, Instantaneous Demand No-shortage Model.

Nonlinear programming: Karush-Kuhn-Tucker necessary and sufficient conditions of optimality, Quadratic programming, Wolfe's method, Beale's method.

Dynamic programming: Bellman's principle of optimality, Recursive relations, Multiplicative and Additive Return function with single additive constraint, Additive Return function with single multiplicative constraint, Applications in Capital-budgeting, Cargo-loading, Shortest-Route finding, Solution of LPP using dynamic Programming.

## Group B: Stochastic process- [Full Marks including IA: 15]

Stochastic Process: Basic Idea and Definition, Classification of Stochastic processes, Stationary Processes, Markov Chain-Introduction, Discrete Parameter Markov Chain, Transition Probabilities, Stochastic matrices, Examples: Random Walk with no Barrier, absorbing barrier, Reflecting Barrier, Markov chains: Definitions, Chapman-Kolmogorov equation, Equilibrium distributions, Classification of states, Long-time behaviour. Stochastic process in continuous time: Poisson process.

## References:


1. F. S. Hillier and G.J. Lieberman, Introduction To Operations Research, McGraw-Hill, 2021.
2. I.C. Hu, Integer Programming and Network Flows, Addison-Wesley, 1970.
3. G. Hadley, Nonlinear and Dynamic Programming, Addison-Wesley, 1972.
4. M.S. Bazaraa, H.D. Sherali, C.M. Shetty, Nonlinear Programming, J. Wiley & Sons.
5. R.E. Bellman and S.E. Dreyfus, Applied Dynamic Programming, Princeton University Press, New Jersey, 1962.
6. Beveridge and Scheehter, Optimization Theory and Practice, McGraw Hill Kogakusha, Tokyo, 1970.
7. Churchman, Ackoff, Arnoff, Introduction to Operations Research, John Wiley and Sons Inc., 1957.

8. G. Hadley and T.M. Whitham, Analysis of Inventory Systems, Prentice Hall, 1963.
9. L. A. Johnson and Montgomery, Operations Research in Production Planning, Scheduling & InventoryControl, John Wiley, 1974.
10. S. S. Rao, Engineering Optimization, Theory and Practice, New Age International (P) Limited Publishers,Third Edition, 2005.
11. Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, S. Chand and Sons.
12. H. A. Taha, Operations Research: An Introduction, Pearson, 10th edition, 2019.
13. M. S. Bartlett, An introduction to Stochastic Process, Cambridge University Press, 1955.
14. Z. Brzezniak and T. Zastawniak, Basic Stochastic Processes, Springer, Indian Reprint, 2005.
15. J. L. Doob, Stochastic processes, John Wiley, New York, 1953.
16. P. G. Hoel, S.C. Port and C. J. Stone, Introduction to Stochastic Processes, Universal Book Stall, NewDelhi, 1993.
17. P.W. Jones and P. Smith, Stochastic Process: An Introduction, 3rd ed., CRC Press, 2020.
18. J. Medhi, Stochastic Processes, Wiley Eastern Ltd., New Delhi, 1983.
19. S. M. Ross, Stochastic Processes, John Wiley and Sons Ltd., 1995.
20. S. Srinivasan and K. Meheta, Stochastic Processes, Tata McGraw-Hill, 2nd edition, 1988.

## Module:-AMT425

## CONTINUUM MECHANICS & COMPUTATIONAL METHODS I

### Group A: Continuum Mechanics-I - [Full Marks including IA: 10]

The Continuum hypothesis. Deformation and flow. Lagrangian and Eulerian descriptions. Material derivative.
Deformation tensor. Finite strain tensor. Small deformation. Infinitesimal strain tensor. Principal strains. Strain invariants. Compatibility equations for linear strains.
Body forces and surface forces. Stress vector. Stress tensor and Stress components. Normal and Shear stresses. Stress deviator. Principal stresses. Stress invariants. Maximum shearing stress. Conservation of mass. The continuity equation. Momentum principles. Equation of motion. Energy balance. First Law of Thermodynamics.
Ideal materials. Classical elasticity. Generalized Hooke's Law. Strain energy Function. Physical interpretation. Isotropic and anisotropic materials.

### Group B: Continuum Mechanics-II - [Full Marks including IA: 25]

**Inviscid incompressible fluid**: Field equations; Bernoulli's theorem and applications; Cauchy's integral; Helmholtz's equations, Impulsive generation of motion, Kelvin's circulation theorem of minimum kinetic energy, Irrotational motion in simply connected and multiply connected regions, Three-dimensional motion, image of a source, sink and doublets with respect to a plane and sphere. Translation of sphere in an infinite liquid, D'Alembert's paradox, Sphere theorem, Axi-symmetrical motion, Stokes' stream function, Two dimensional motion, Stream function, complex potential, motion of translation and rotation of circular and elliptic cylinders in an infinite liquid, circle theorem, Blasius theorem, Kutta-Joukowski's theorem.

Constancy of circulation. Permanence of vortex lines and filaments. Equation of surface formed by the streamlines and vortex lines in the case of steady motion, System of vortices, Rectilinear vortices, Vortex pair and doublets, Image of vortex with respect to a circle. A single infinite row of vortices, Karman's vortex sheet, Pair of stationary vortex filament behind a circular cylinder in a uniform flow.

Surface waves, progressive waves in deep and shallow water, Stationary waves, energy and group velocity, waves at the interface of two liquids.

**Viscous incompressible fluid flow:** Field equations, Boundary conditions, Reynold's number, Vorticity equation, Circulation, Flow through parallel plates, Flow through pipes of circular and elliptic cross sections.

## Group C: Computational Methods I -[Full Marks including IA: 15]

Computer Number System: Control of round-off-errors, Instabilities - Inherent and Induced, Hazards in approximate computations, Well-posed and ill-posed problems, Well posed computations.

Numerical Solution of System of Linear Equations: Triangular factorisation methods, Matrix inversion method, Operation counts, Error analysis, Ill conditioned matrix, Iterative methods, Convergence of iterative methods, Relaxation methods, Successive-Over Relaxation (SOR) method, Convergence of SOR method, Solution of over-determined system of linear equations - Least squares method.

Solution of Non-linear Equations: Single Equation - Aitken's -method and Steffensen's iteration.

Roots of Real Polynomial Equations: - Bairstow's method of quadratic factors, Quotient-difference method, Graeffe's root squaring method, Sensitivity of polynomial roots. Non-Linear System of Equations - Newton's method, Quasi-Newton's method.

## References:


1. Y.C. Fung. Foundations of Solid Mechanics. Prentice-Hall, Englewood, 1965.
2. A.C. Eringen. Mechanics of Continua. John Wiley and Sons, New York, 1967.
3. R. M. Bowmen. Introduction to Continuum Mechanics for Engineers. Plenum Press, New York, 1989.
4. D. S. Chandrasekharaiah and L. Debnath, Continuum Mechanics, Inc. Academic Press, Boston, 1994.
5. P. D. S. Verma: Theory of Elasticity. Vikas Publishing House Pvt. Ltd., 1997.
6. A. Ralston, A First Course in Numerical Analysis, McGraw Hill, N. Y., 1965.
7. A. Ralston and P. Rabinowitz, A First Course in Numerical Analysis, McGraw Hill, N.Y, 1978.
8. S.D. Conte and C. DeBoor. Elementary Numerical Analysis: An Algorithmic Approach, McGraw Hill, N.Y., 1980.
9. K.E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons, 1989.
10. L. Colatz, Functional Analysis and Numerical Mathematics, Academic Press, N.Y, 1966.
11. C.T.H. Baker and C. Phillips, The Numerical Solution of Nonlinear Problems, C.P. Oxford, 1981.
12. C.E. Fröberg. Introduction to Numerical Analysis, Addison-Wesley Publishing Company, 1969.
13. R. Zurmuhl, Numerical Analysis for Engineers and Physicists, Allied Publishers Private

Limited, Calcutta.
14. E.K. Blum, Numerical Analysis and Computation Theory and Practice, Addison-Wesley Publishing Company, Inc., London, 1972.
15. C. Pozrikidis, Numerical Computation in Science and Engineering, Oxford University Press, Inc., N.Y., 1998.
16. J.H. Wilkinson, Rounding Errors in Algebraic Processes, Prentice Hall, Englewood Cliffs, N.J., 1963.