# DEPARTMENT
# OF
# APPLIED MATHEMATICS

# UNIVERSITY OF CALCUTTA

## SYLLABUS OF M. SC.
## IN APPLIED MATHEMATICS
## TWO-YEAR(FOUR-SEMESTER)
## CHOICE BASED CREDIT COURSE

**WITH EFFECT FROM ACADEMIC SESSION 2021 -22**

# UNIVERSITY OF CALCUTTA

## NotificationNo.CSR/20/2022

It is notified for information of all concerned that the Syndicate in its meeting held on 08.12.2021 (vide Item No.28) approved & confirmed the revised syllabus of M.Sc. Applied Mathematics, offered by Department of Applied Mathematics, under this University, as laid down in the accompanying pamphlet.

The above shall be effective from the session 2021 -2022.

SENATE HOUSE

KOLKATA-700 073

The 9th June, 2022

Prof.(Dr.) Debasis Das

Registrar

UNIVERSITY OF CALCUTTA REGISTRAR

# REGULATIONS FOR TWO-YEAR(FOUR-SEMESTER) M.Sc. DEGREE COURSE IN APPLIED MATHEMATICS UNDER THE UNIVERSITY OF CALCUTTA

The examination for the degree of Master of Science (M.Sc.) shall consist of four semesters, Semesters 1, 2, 3 and 4. Each semester examination will be held after the completion of the modules for that particular semester and before the next semester begins. The University authority will decide commencing on such date and time and it will be duly notified. The total duration of the course is two years (hereafter, “course” refers to the M.Sc. course in Applied Mathematics and “module” refers to the individual modules of 50 marks each). The duration of the semester examinations shall be as follows ordinarily:

| | |
|---|---|
| 1st Semester | July to December |
| 2nd Semester | January to June |
| 3rd Semester | July to December |
| 4th Semester | January to June |

The structure of the revised syllabus for the M.Sc. course in Applied Mathematics applicable from the academic year **2021-22**, will be as follows:

**FIRST SEMESTER MODULES**

AMATH 411 Classical Mechanics and Introductory Quantum Theory...50 Marks

AMATH 412 Abstract and Linear Algebra
- Gr-A: Abstract Algebra ......................................................30Marks
- Gr-B: Linear Algebra ..........................................................20 Marks

AMATH 413 Real Analyses .....................................................................50 Marks

AMATH 414 Complex Analysis and Theory of Ordinary Differential Equations
- Gr-A: Complex Analysis ...................................................30 Marks
- Gr-B: Theory of Ordinary Differential Equations............ 20 Marks

AMATH 415 Partial Differential Equations, Generalised Functions and Integral Transforms

Gr-A: Partial Differential Equations..................................25 Marks
Gr-B: Generalised Functions & Integral Transforms........25 Marks

**SECOND SEMESTER MODULES**

AMATH 421 Continuum Mechanics-I and Rigid Dynamics
Gr-A: Continuum Mechanics I.......................................25 Marks
Gr-B: Rigid Dynamics....................................................25 Marks
AMATH 422 Continuum Mechanics II...............................................50 Marks
AMATH 423 Topology, Functional Analysis & Operator Theory......50 Marks
AMATH 424 Optimization Techniques and Calculus of Variations
Gr-A: Optimization Techniques....................................30 Marks
Gr-B: Calculus of Variations........................................20 Marks
AMATH 425 Theory of Relativity, Classical Field Theory and Electromagnetism
Gr-A: Theory of Relativity, Classical Field Theory.....25 Marks
Gr-B: Classical Electromagnetism ................................25 Marks

**THIRD SEMESTER MODULES**

AMATH 531 Discrete Mathematics, Graph Theory and Nonlinear Dynamics
Gr-A: Discrete Mathematics...........................................20 Marks
Gr-B: Graph Theory......................................................20 marks
Gr-C: Nonlinear Dynamics…........................................10 Marks
AMATH 532 Numerical Analysis......................................................50 Marks
AMATH 533 Advanced Paper 1.........................................................50 Marks
CBCC-A* Choice Based Credit Course-A .................................50 Marks
CBCC-B* Choice Based Credit Course-B.................................50 Marks

***The students will select these two modules from a list of CBCC papers prescribed by the University from master degree courses of other disciplines.**

**FOURTH SEMESTER MODULES**

AMATH 541 Numerical Practical ......................................................50 Marks
AMATH 542 Stochastic Process, Differential Equation and Stability
Gr-A: Stochastic Process ...................................................20 Marks
Gr-B: Stochastic Differential Equations.............................20 marks
Gr-C: Stochastic Stability of Differential Equations................10 Marks
AMATH 543 Advanced Paper 2..............................................................50 Marks
AMATH 544 Advanced Paper 3.............................................................50 Marks
AMATH 545 Integral Equations & Wavelet Transforms and Project
Gr-A: Integral Equations & Wavelet Transforms............25 Marks

Gr-B: Project.......................................................................25 Marks

The course of total 1000 marks is divided into 20(twenty) modules (including Project) each module carries full marks 50(fifty).

## LIST OF ADVANCED PAPERS

## FOR MODULE AMATH 533 ( For 3rd SEMESTER )

AMADV 5301 BASICS OF QUANTUM MECHANICS
AMADV 5302 INCOMPRESSIBLE FLUID MOTION
AMADV 5303 DYNAMICAL MODELS OF ECOLOGY
AMADV 5304 PLASMA KINETIC THEORY
AMADV 5305 ADVANCED OPTIMIZATION AND OPERATIONS RESEARCH -I
AMADV 5306 ADVANCED COMPUTATIONAL METHODS-I
AMADV 5307 THEORY OF ELASTICITY I
AMADV 5308 GEODESY AND GEOPHYSICS-I
AMADV 5309 DYNAMICAL METEOROLOGY
AMADV 5310 DYNAMICAL SYSTEM I
AMADV 5311 GENERAL RELATIVITY
AMADV 5312 ALGORITHMS AND DATA STRUCTURE

## FOR MODULES AMATH 543 and AMATH 544 ( For 4th SEMESTER )

AMADV 5401 QUANTUM INFORMATION AND QUANTUM COMPUTATION
AMADV 5402 QUANTUM FIELD THEORY
AMADV 5403 COMPRESSIBLE FLOW
AMADV 5404 TURBULENCE
AMADV 5405 COMPUTATIONAL FLUID DYNAMICS
AMADV 5406 DYNAMICS OF COMPLEX ECOLOGICAL SYSTEMS
AMADV 5407 FRACTALS AND CHAOS
AMADV 5408 MATHEMATICAL MODELS IN PHYSIOLOGY AND MEDICINE
AMADV 5409 ECONOPHYSICS
AMADV 5410 FLUID PLASMA THEORY
AMADV 5411 INSTABILITIES AND NONLINEAR PLASMA THEORY
AMADV 5412 ADVANCED OPTIMIZATION-II
AMADV 5413 ADVANCED OPERATIONS RESEARCH-II
AMADV 5414 ADVANCED COMPUTATIONAL METHODS-II
AMADV 5415 ADVANCED COMPUTATIONAL METHODS-III
AMADV 5416 THEORY OF ELASTICITY II

AMADV 5417 THEORY OF ELASTICITY III
AMADV 5418 GEODESY AND GEOPHYSICS-II
AMADV 5419 GEODESY AND GEOPHYSICS-III
AMADV 5420 ATMOSPHERIC THERMODYNAMICS
AMADV 5421 METEOROLOGICAL FORECASTING AND ANALYSIS
AMADV 5422 DYNAMICAL OCEANOGRAPHY
AMADV 5423 DYNAMICAL SYSTEM II
AMADV 5424 DYNAMICAL SYSTEM III
AMADV 5425 GRAVITATION AND BLACK HOLES
AMADV 5426 COSMOLOGY
AMADV 5427 ASTROPHYSICS AND RELATED DATA ANALYSIS
AMADV 5428 THEORY OF AUTOMATA
AMADV 5429 DATABASE MANAGEMENT SYSTEMS; GRAPH THEORY AND COMBINATORICS
AMADV 5430 ASTROSTATISTICS

**Annexure – I**

## **<u>Choice Based Credit Course :: 50 Marks</u>

## Some Methods in Applied Mathematics

**Gr-A : Differential equations: (30 Marks)**

**Gr-B : Numerical Analysis: (20 Marks)**

****This module is offered by the Department of Applied Mathematics as one CBCC module paper for the master degree students of other disciplines of the University of Calcutta.**

# DETAILED SYLLABUS

## Module:-AMATH 411

## CLASSICAL MECHANICS AND INTRODUCTORY QUANTUM THEORY

Mechanics of a system of particles: Constraints; Generalized coordinates; Virtual displacement and principle of virtual work; D'Alembert's principle; Generalized forces; Lagrangian; Lagrange's equations of motion; velocity dependent potential; Principle of energy; Rayleigh's dissipation function.

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

Canonically conjugate coordinates and momenta; Legendre transformation; Hamiltonian; Hamilton's equations from variational principle; Poincare-Cartan integral invariants; Principle of stationary action; Fermat's principle; Canonical transformation; Generating function; Poisson Bracket; Equations of motion; Action-angle variables; Hamilton-Jacobi's equation; Hamilton's principal function; Hamilton's characteristics function; Liouville's theorem.

Planck's Law, Photo-electric effect; Bohr's theory, Compton effect; de Broglie waves; Wave-particle dualism; Minimum uncertainty product; Need for a new mechanics; Fundamental laws and foundations of quantum mechanics; Schrödinger equation; Introductory concepts of quantum states, observables and density matrix formalism.

**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. P.A.M. Dirac, The Principles of Quantum Mechanics, 4th ed., Oxford University Press, Oxford, 1981.
14. R.P. Feynman, The Feynman Lectures on Physics, 3 Vols., Narosa Publ., New Delhi, 1990.
15. T.F.Jordan, Quantum Mechanics in Simple Matrix Form, Dover Publ., 2005.
16. M. Chester, Primer of Quantum Mechanics, Dover Publ., 2003.
17. J.P. McEvoy and O. Zarate, Introducing Quantum Theory, Icon Books UK, Singapore, 2003.

## Module:-AMATH 412

## ABSTRACT AND LINEAR ALGEBRA

**Group-A:**
**Abstract Algebra: (30 marks)**

Review of general concepts in classical algebraic systems, Generator of an arbitrary group, Commutator subgroup, Group Action; Conjugacy classes, The class equation, Cauchy's theorem, Sylow's p-subgroups, Sylow's theorems and applications; Normal and subnormal series, Composite series, Jordan-Holder theorem, Solvable groups, Nilpotent groups.

Group representations, Reducible and irreducible representations, Schur's lemma, Orthogonality theorem, Characters of a representation, Continuous groups, Lie groups and their algebras; generators of a lie group .The linear groups, Orthogonal groups and unitary groups with examples, Applications.

Basic recollections of rings, Integral domains, Fields; Characteristic of an integral domain, Noetherian rings, Hilbert basis theorem, Polynomial rings, Division algorithm, Irreducibility criteria, Eisenstein's criterion (statement only).
Field extensions, Algebraic extensions; Splitting fields; The Galois group of a polynomial, The fundamental theorem of Galois theory; Finite fields.

**Group-B:**
**Linear Algebra: (20 marks)**

**Review**: Isomorphism, Linear Transform, Rank inequalities, Nonsingularity. Partitioned Matrices, Bloch-Diagonal and Bloch-Triangular matrices. Similarity Transformation.
**Unitary Equivalence**: Unitary matrices, Euclidean Isometry and Unitary transformation, Unitary Similarity, QR factorization. Schur's Triangularization and its consequences.
**Generalized Inverse**: Definition, Basic properties,
**Congruence:** Properties of Hermitian matrices, Congruence Transformation, Orthogonal diagonalizability of Hermitian matrices.
**Special Classes of Matrices**: Positive Definite and Semi-definite Matrices, Normal Matrices. Polar and Singular value decomposition.
**Linear operators:** Hermitian, Normal and Unitary operators; Functions of operators; Spectral decomposition, Spectral theorems for the Hermitian and normal operators on finite dimensional vector spaces.

**References :**


1. I.N.Hersein, Topics in Algebra, 2nd Ed.New Delhi Wiley 2006.
2. J.B.Fraleigh, A first course in Abstract Algebra, 7th Ed.Pearson, 2005.
3. N.Jacobson, Basic Algebra, Dover Publications, 2009.
4. M.Artin, Algebra, Pearson,2007.
5. D.S.Dummit and Foote, Abstract Algebra, 3rd Ed.John Wiley & Sons, 2011.
6. Malik , Mordeson and Sen, Fundamentals of Abstract Algebra, Tata McGrew-Hill, 1997.
7. P.B.Bhattacharya, S.K.Jain and S.R. Nagpal, Basic Abstract Algebra, Cambridge University Press, 2005.
8. P.M.Cohn, Basic Algebra, Springer,2005.
9. R.Gilmore, Lie Groups, Lie Algebras some of their applications, John Wiley, New York,1995
10. M. Suzuki, Group Theory – *1,Springer,2014*.
11. Faulton, The Representation Theory of finite groups, Lecturenotes in Maths, Springer, 1978.
12. J.S.Rose, A Course on Group Theory, Dover Publication, 2012.
13. A.R. Rao and P. Bhimasankaram, *Linear Algebra*, Hindustan Book Agency, 2000.
14. K. Hoffman and R. Kunze, *Linear Algebra*, Prentice Hall of India, 2003.
15. R.A. Horn and C.R. Johnson, *Matrix Analysis*, Cambridge University Press, 2012.
16. R. Bhatia, *Matrix Analysis*, Springer-Verlag, New-york, 1997.

17. S. Roman, Advanced Linear Algebra, Springer, 2007.
18. G. Birkoff and S. Mac Lane, *A Survey of Modern Algebra*, A.K. Peters Ltd., 1998.
19. P.R. Halmos, *Finite Dimensional Vector Spaces*, Springer-Verlag, 1987.
20. G. Strang, *Introduction to Linear Algebra*, Wellesley Cambridge Press, 2003.
21. G. E. Shilov, *Linear algebra,* Dover Publ., 1977.
22. H. Dym, *Linear Algebra in Action,* American Mathematical Soc., 2006.
23. T.B. Blyth and E.F. Robertson, *Further Linear Algebra*, Springer, 2001.
24. F. Zhang, *Matrix Theory*, 2nd Ed., Springer, 2011.

## Module:-AMATH 413

## REAL ANALYSIS

Bounded and totally bounded metric spaces; Completeness and Baire category theorems; Compact and separable metric spaces. Functions on metric spaces. Homeomorphism, equivalent metrics and isometry; Contraction mapping. Banach fixed point theorem and its applications. Concept of equicontinuity between metric spaces. Locally Compact Spaces.

Introductory concepts on Banach space, Hilbert space. Simple properties. Wierstrass approximation theorem.

Functions of bounded variation. Decomposition theorem, Derived function. Derivates. Absolute Continuity.

Trigonometric Fourier Series of Functions in $L[-\pi, \pi]$, $L^2[-\pi, \pi]$, convergence at a point. Cesaro summability of Fourier series. Fourier series in Hilbert spaces.

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. $L^p$ 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. H.L. Royden, Real Analysis, 3rd ed., Macmillan Publishing Co., Inc., New York, 1989.
2. E.C. Titchmarsh, Theory of Functions, Clarendon Press, 1932.
3. T.M. Apostal, Mathematical Analysis, Wesley, Reading, 1974.
4. I.P. Natanson, Theory of Functions of a Real Variable, Vols. I & II, Akademie-Verlag, Berlin, 1981.
5. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, Singapore, 1963.
6. M.E. Munroe, Measure and Integration, Addison Wesley, 1953.
7. A.E. Taylor, General Theory of Functions and Integration, Blaisdell, 1965.
8. S. Saks, Theory of Integrals, Warsaw, 1937.
9. Hewitt and Stormberg, Real and Abstract Analysis, 3rd ed., Springer-Verlag, New York, 1975.
10. E.W. Hobson, Theory of Functions of a Real Variable, Vols. I & II, Dover Publ., 1957.
11. H.S. Carslaw, Fourier Series and Integrals, Dover Publ., 1930.
12. S.K. Berberian, Measure and Integration, McMillan, New York, 1965.
13. J.C. Burkill, The Lebesgue Integral, Cambridge University Press, 1961.
14. P.R. Halmos, Measure Theory, Narosa Publ., Student ed., 1981.
15. Donald L. Cohn, Measure Theory, Birkhauser, Boston, 1980.
16. A.N. Kolmogorov and S.V. Fomin, Introductory Real Analysis, Dover Publ., 1975.
17. E.T. Copson, Metric Spaces, Cambridge University Press, Cambridge, 1968.
18. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill, New York, 1976.
19. A. Gupta, Real and Abstract Analysis, Academic Publishers, Kolkata, 2002.
20. C.D. Aliprantis and O. Burkinshan, Principles of Real Analysis, 3rd ed., Academic Press, 1998.


## Module:-AMATH 414

## COMPLEX ANALYSIS AND THEORY OF ORDINARY DIFFERENTIAL EQUATIONS

**Group-A:**
**Complex Analysis: (30 marks)**

Complex numbers, Topology of the complex plane, sequence of complex numbers, Stereographic projection.
Analytic functions, Cauchy-Riemann equations, Zeros of analytic functions, multiple valued functions, Branch cuts, Concept of Riemann sheet.
Curves in the complex plane, Complex integration, Jordan's Lemma. Cauchy's theorem, Morera's theorem, Cauchy integral formula, Maximum 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, Argument principle, Rouche's theorem, Hurwitz theorem.
Conformal mapping, Mobius transformation.

**Group-B:**
**Theory of Ordinary Differential Equations: (20 marks)**

Existence and Uniqueness of solutions of initial value problems for first order ordinary differential equations, Lipschitz condition, Picard- Lindeloeff theorem. Singular solutions of first order ODEs.
The linear ODE of nth order. Existence and uniqueness of solutions.
Linear homogeneous differential equation: Method of Frobenius, Fuch's theorem, Equations of Fuchsian type.
Linear non-homogeneous differential equation: Strum -Liouville's equation. Eigen value problem, Properties of eigenvalues and eigenfunctions for a SturmLiouville problem. Completeness of eigenfunctions. Fourier expansion in terms of orthonormalised characteristic functions. Integral representation and Green's function. Properties of Green's Function.
System of ODE's Flow diagram, Phase portrait, Isocline. Fixed points and their nature. stability, asymptotic stability, Liapunov function, Linearization at a critical point. Lotka-Volterra model.
Special functions: Legendre function. Rodrigues formula. Schlafli and Laplace's integral representation. Orthogonal property. Recurrence relations.
Bessel function. Orthogonal property. Recurrence relations. Schlafli's integral representation.
Hypergeometric function. Pochhammer's integral representation. Confluent hypergeometric function

**References:**


1. E.T. Copson, An introduction to theory of functions of a complex variable, Oxford, Clarendon Press, 1962.
2. E.T. Whittaker and G.N. Watson, A course of modern analysis, Cambridge University Press, 1958.
3. R.V. Churchill, J.W. Brown and R.E. Vermay, Complex variables and applications, McGraw Hill, 1984.
4. T.M. MacRobert, Functions of a complex variable, MacMillan, 1962.
5. I.N. Sneddon, Special functions of Mathematical Physics and Chemistry, Longman, 1980.

6. E.A. Coddington and N. Levison, Theory of Ordinary Differential Equations, Tata McGraw Hill, 1955.
7. E.L. Ince, Ordinary Differential Equations, Dover, 1956.
8. E.D. Rainville, Special Functions, MacMillan, 1960.
9. N.N. Labedev, Special Functions, and their applications, Dover, 1972.
10. L.V. Ahlfors, Complex Analysis, McGraw Hill, 1978.
11. M.J. Ablowitz, Complex Variables: Introduction and Applications, Cambridge University Press, 1997.
12. W. Rudin, Real and Complex Analysis, McGraw Hill, 1986.
13. H.A. Priestley, Introduction to complex analysis, Indian Edition, 2006.
14. J.B. Conway, Functions of one complex variable I and II, Springer-Verlag, New York, 2005 and 1995.

## Module:-AMATH 415

## PARTIAL DIFFERENTIAL EQUATIONS, GENERALISED FUNCTIONS AND INTEGRAL TRANSFORMS

**Group-A:**
**Partial Differential Equations: (25 marks)**

Hyperbolic, Parabolic and Elliptic partial differential equations: Solution using separation of variable method in Cartesian and polar coordinates. Vibration, heat conduction and potential problems. Solution of partial differential equations with discontinuous first derivatives. Weak solutions. Concentrated source or force terms. Vibration of a loaded string. Point sources and fundamental solutions. Energy integrals. Well posed and Ill posed character.
Integral theorems and Green’s functions. Green’s functions for bounded regions: Eigen function expansions. Green’s functions for unbounded regions. Method of images.
Concept of nonlinearity, dispersion and dissipation. Wave breaking, soliton and shock. Solution of Burger equation and KdV equation. Cole-Hopf transformation.
Perturbation methods.

**Group-B:**
**Generalized Functions and Integral Transforms: (25 marks)**

**Generalized Functions:**
The Dirac Delta function and Delta sequences. Test functions. Linear functionals. Regular and singular distributions. Sokhotski-Plemelj equation. Operations on

distributions. Properties of the generalized derivatives. Some transformation properties of the delta function. Convergence of distributions.

**The Fourier Transform:**

Fourier series, Algebraic properties of Fourier transform, Convolution, Translation, Modulation. Analytical properties of Fourier transforms, Transform of derivatives and derivatives of transform, Perseval formula, Inversion theorem, Plancherel's theorem, Application to solving ordinary and partial differential equation.

**The Laplace transform:**

Algebraic properties of Laplace transform, Transform of derivatives and derivatives of transform. The inversion theorem, Evaluation of inverse transforms by residue. Asymptotic expansion of inverse transform, Application to solving P.D.E., Integral equation, etc.

**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.

**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.

**References:**


1. R. Courant and D. Hilbert, Methods of Mathematical Physics (2 Vols.), Wiley, New York, 1966.
2. Lawrence C. Evans, Partial Differential Equations, Second Edition, American Mathematical Society, 2014.
3. I.N. Sneddon, Elements of partial differential equations, McGraw Hill, 1986.
4. Erich Zauderer, Partial Differential Equations of Applied Mathematics, A Wiley-Interscience Publication, John Wiley and Sons, 1983.
5. H.F. Weinberger, A first course in partial differential equations, Blaisdell, 1965.
6. C.R. Chester, Techniques in partial differential equations, McGraw Hill, New York, 1971.
7. K.S. Rao, Introduction to partial differential equations, Prentice Hall, New Delhi, 1997.
8. A. Sommerfeld, Partial differential equations in physics, Academic Press, New York, 1967.
9. V. Vladimirov, Equations of mathematical physics. Dekker, New York, 1971.
10. I. Stakgold, Green's functions and boundary value problems, Wiley, New York, 1979.
11. G.E. Shilov, Generalized functions and partial differential equations, Gordon and Breach, New York, 1968.
12. R.F. Hoskins, Generalized functions, Horwood, Chichester and New York, 1979.

13. I.M. Gelfand and G.E. Shilov, Generalized functions, Academic Press, New York, 1964.
14. R.P. Kanwal, Generalized Functions: Theory and Technique, Birkhauser, New York, 1998.
15. D.S. Jones, Generalized Functions, Cambridge University Press, 1982.
16. I.N. Sneddon, Fourier Transform, McGraw Hill, 1951.
17. F.C. Titchmash, Introduction to the theory of Fourier Integrals, Oxford Press, 1937.
18. Peter, K.F. Kahfitting, Introduction to the Laplace Transform, Plenum Press, N.Y., 1980.
19. E.J. Watson, Laplace Transforms and Application, Van Nostland Reinhold Co. Ltd., 1981.
20. E.I. Jury, Theory and Application of Z-Transform, John Wiley and Sons, N.Y.
21. R.V. Churchill, Operational Mathematics, McGraw Hill, 1958.
22. D. Loknath, Integral Transforms and their Application, C.R.C. Press, 1995.

## Module:- AMATH 421

## CONTINUUM MECHANICS-I AND RIGID DYNAMICS

**Group-A:**
**Continuum Mechanics-I: (25 marks)**

The Continuum hypothesis. Deformation and flow. Lagrangian and Eulerian descriptions. Material derivative. Deformation tensors. 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 components. Normal and Shear stresses. Stress deviator. Principal stresses. 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. Beltrami-Michel compatibility equations.

Field equations in linear elasticity. Elastostatic problem and uniqueness of solution. Elastodynamic problem and uniqueness of solution. Axial extension of a beam. Bending of a beam by terminal couples. Torsion of a circular beam. Stress waves in a semi-infinite beam. Plane waves in unbounded elastic body.

**Group-B:**
**Rigid Dynamics: (25 marks)**

Degree of freedom, Configuration Space: Topology and Representation
Kinetic energy, Angular momentum, Stability of rotation about an axis, Motion of heavy symmetric top (Lagrangian formulation, Equation of motion, Analysis).
Euler equations of motion. Torque free motion. Motion of a free top about a fixed point. Small oscillations about equilibrium of a rigid body motion.

Spherical displacements, Spatial Displacements, screw axis, screw displacements**,**
Rotations and Angular Velocities; Euler’s Theorem (with proof),
Rotation Matrices; Angular Velocities; Rodrigues' formula for rotations
Exponential Coordinate Representation of Rotation;
Motion of a rigid body, Norm of displacements, The Derivative of a motion, Rigid body motion in arbitrary dimensions ( Lagrangian, Equation of motion, Euler Equation, conserved quantities, Noether’s theorem and angular momentum, Examples), The tangent operators of SO(n), Vectors Associated with Tangent Operators, Multi-Parameter Motion.
Screw theory, screw coordinate transformations, bi-vectors, Screw Systems, Dual Orthogonal Matrices**,**

**References:**


1. Y.C. Fung. *Foundations of Solid Mechanics*. Prentice-Hall, Englewood, 1965.
Cliffs, NJ.
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. H. Goldstein. *Classical Mechanics*, Narosa Publishing House, New Delhi 1998.
7. VI Arnold. *Mathematical Methods of Classical Mechanics, 2$^{nd}$ Ed*. Springer, 1989.
8. T.W.B. Kibble. *Classical Mechanics*, Longman, NY, 1986.
9. F.R. Gantmacher. *Analytical Mechanics*, Mir Publishers, Moscow, 1975.
10. A.K. Raychaudhuri. *Classical Mechanics*, A course of lectures, Oxford University Press, Calcutta, 1983.
11. N.C. Rana and P.S. Joag. *Classical Mechanics*, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1991.

# Module:- AMATH 422

# CONTINUUM MECHANICS-II

**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.

**Inviscid Compressible Fluid:** Field equations, Circulation, Propagation of small disturbance. Mach number and cone, Bernoulli's equation. Irrotational motion, Velocity potential. Bernoulli's equation in terms of Mach number. Pressure, density, temperature in terms of Mach number, Critical conditions. Steady channel flow, Area-velocity relation. Mass flow through a converging nozzle. Flow through a de-Laval nozzle. Normal shock waves, Governing equations and the solution. Entropy change.

**References:**


1. H. Lamb, Hydrodynamics, Dover Publication.
2. L.M. Milne-Thomson, Theoretical Hydrodynamics.
3. L. Prandtl, Essential of Fluid Dynamics, Hafnen, Pub. Co.
4. P.K. Kundu and Iva M.Cohen, Fluid Dynamics, Har Court, India.
5. J.J. Stoker, Water waves, the mathematical theory with application, Interscience Publ.
6. S.I. Pai, Viscous Flow Theory, Princeton.
7. F. Chorlton, Text Book of Fluid Dynamics, CBS Publ.

# Module:- AMATH 423

# TOPOLOGY, FUNCTIONAL ANALYSIS & OPERATOR THEORY

**Topology:**
Topological spaces: Elementary concepts, continuity, convergence, homeomorphism. Open bases and open subbases. Weak topologies. First and Second countability, Separable spaces.

Compactness, Connectedness, Local and Path connectedness, Separation axioms, Urysohn's Lemma and Tietze extension Theorem(statement only). Subspaces, Product Spaces, Quotient spaces. Tychonoff's theorem. Metrizability, Paracompactness and Urysohn's Metrization Theorem (statement only). Revision of characterization of compactness in metric spaces. Ascoli-Arzela's theorem.

**Functional Analysis & Operator Theory:**

Linear spaces: Normed linear spaces, Linear topological spaces, Banach spaces, 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).

Linear functionals: Dual spaces, reflexive property, 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.

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. Compact and Completely continuous operators. Adjoint operator, Self-adjoint operators; Symmetric operators; Normal and Unitary operators; Hilbert-Schmidt theorem, Eigenvalues and their properties. Spectral theorem for bounded normal operators.

**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, $4^{th}$ 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.W. Rudin, Functional Analysis, Tata McGraw Hill, New Delhi, 1992.
8. M. Reed and B. Simon, Functional Analysis, Academic Press, Inc., London, 1980.
9. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
10. K. Yosida, Functional Analysis, Springer Verlag, 1995.
11. N. Dunford and J.T. Schwartz, Linear Operators, 3 Volumes, Interscience / Wiley, New York, 1958-1971.
12. Ola Bratteli and D.W. Robinson, Operator Algebra and Quantum Statistical Mechanics 1, Springer-Verlag, New York, 1979.
13. A.N. Kolmogorov and S.V. Fomin, Elements of the Theory of Functions and Functional Analysis, 2 Vols., Graylock, Rochester, 1957 & 1961.
14. R.V. Kadison and J.R. Ringrose, Fundamentals of the theory of operator algebras, Vol. I & Vol. II, American Mathematical Society, 1997.

## Module:- AMATH 424

## OPTIMIZATION TECHNIQUES AND CALCULUS OF VARIATIONS

**Group-A:**
**Optimization:(30 marks)**

Linear programming, Revised simplex method, Dual simplex method, Post optimal analysis.
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, System with more than one constraint, Solution of LPP using dynamic Programming.
Integer programming, Gomory's cutting plane method , Branch and bound technique.
Inventory control, Concept of EOQ, Problem of EOQ with finite rate of replenishment, Problem of EOQ with shortages, Multi-item deterministic problem, Probabilistic inventory models.
Elements of Fuzzy set theory and its relevance in representing uncertainties, Fuzzy linear programming.

**Group-B:**
**Calculus of Variations:(20 marks)**

Basic Lemma. Fundamental problem and its solution. Case of several dependent variables. Applications to geodesics on a surface. Hamilton’s variational principle, brachistochrone.

Variable end-point conditions; Extended problem and its solution. Lagrange’s problem – Holonomic and Non-holonomic constraints. Solutions of holonomic and Non-holonomic Lagrange’s problems with generalizations to several dependent variables. Mixed Lagrange’s problem and its solution. Application to the Principle of Least Action.

Isoperimetric problem and its solution.

Basic Lemma and fundamental problem in two and three dimensions.

**References:**


1. G. Hadley, Nonlinear and Dynamic Programming, Addison-Wesley, 1970.
2. M.S.Bazaraa, H.D.Sherali, C.M. Shetty, Nonlinear Programming, J.Wiley & Sons,2002.
3. T.C. Hu, Integer Programming and Network Flows, Addison-Wesley,1972.
4. H. A.Taha, Operations Research, MacMillan Publ.,1982.
5. M.C. Joshi and K. Moudgalya, Optimization Theory and practice, Narosa Publishing House, New Delhi, 2004.
6. O. Guler, Foundations of Optimization, Springer 2010.
7. D. Nag and P. Basu, Introduction to operations research, Tata Mc Graw Hill, 2012.
8. Ravindran, Phillips, Solberg, Operations Research Principles and Practice, John Wiley and Sons,1987.
9. J.C. Pant, Introduction to Optimization, New Delhi, Jain Brothers, 1983.
10. H.J. Zimmermann, Fuzzy Set Theory and Its Applications, Allied Publishers Limited, 1996.
11. A.S. Gupta, Calculus of Variations with Applications, Prentice Hall, 1997.
12. G.M. Ewing, Calculus of variations with Applications, Dover Publications, 1985.
13. R. Weinstock, Calculus of Variations, Dover Publications, 1974.

# Module:- AMATH 425

# THEORY OF RELATIVITY, CLASSICAL FIELD THEORY AND ELECTROMAGNETISM

## Group-A:
**Theory Of Relativity, Classical Field Theory (25 Marks)**

Galilean Transformations; Inertial frame; Michelson-Morley experiment. Lorentz transformations. Simultaniety, Time-dilation and Lorentz contraction. Minkowski diagram; LT through Minkowski diagram; Constancy of speed of light; Acceleration under LT. Metric tensor; properties of metric tensors; Space like and Time like intervals, Relativistic momentum and energy.

Fields, Action Principle, Scalar Field, Euler-Lagrange equation, Particles and Fields, Time independent Field and Poisson Equation, Vector Field, Covariant and Contravariant Vectors, Tensors, Electromagnetic Fields, Field Equations, Derivation of Maxwells equations and Equation of Continuity from Generalized Field Equations

## Group-B:
**Classical Electromagnetism: (25 marks)**

Coulomb's law, Electric field, Electrostatic potential, Gauss's Law, Applications, Potentials for simple systems: thin spherical shell, infinitely long wire and charged disc. Electric dipole. Electric dipole in an external electric field. Multipole expansion. Poisson's equation, Laplace equation, Green functions, Method of images. Solutions of Laplace and Poisson equation, Energy of the electrostatic field. Green's reciprocity theorem. Electrostatic boundary conditions.

The Lorentz force and magnetic field. Ampere's circuital law and its applications. Solenoids, Helmholtz's theorem. Vector potential. Simple examples. Field of a small current loop. Magnetic dipole. Magnetic dipole in an external magnetic field. Biot-Savart law and Its Applications. Magnetostatic boundary conditions.

Faraday's law; Generalisation of Ampere's law; Displacement current. Electromagnetic potentials and wave equations. Gauge transformations. Coulomb and Lorentz gauges. Plane electromagnetic waves (potential formulation). Green's functions; Advanced and Retarded Potentials; Poynting vector. Covariance of Maxwell equations.

**References:**


1. Special Relativity and Classical Field Theory: Leonard Susskind and Art Friedman.

2. Introduction to Special relativity : Robert Resnick
3. T. Padmanavan, Theoretical astrophysics, Vols. 1-3, Cambridge University Press.
4. S. Banerjee and A. Banerjee, General Relativity and Cosmology, Elsevier.
5. R. Adler, M. Bazin and M. Schiffer, Introduction to General Relativity, McGraw Hill.
6. B.F. Schutz, A first course in General Relativity, 2nd ed., Cambridge University Press.
7. J. B. Hartle, Gravity: An Introduction to Einstein's General Relativity.
8. J.H. Jeans, Mathematical Theory of Electricity and Magnetism, Cambridge University Press, 1957.
9. V.S.A. Ferraro, Electromagnetic Theory, Athlone Press, London, 1962.
10. D.J. Griffiths, Introduction to Electrodynamics, Prentice Hall, New Delhi, 2000.
11. T.L. Chow, Introduction to Electromagnetic Theory: A Modern Perspective, Jones and Bartlett Publishers, Inc., 2006.
12. A Das, Lectures on Electromagnetism, Hindustan Book Agency, New Delhi, 2004.
13. J.V. Narlikar, Introduction to Cosmology, Cambridge University Press.
14. S. Weinberg, Gravitation and Cosmology, Wiley.
15. A. Einstein, The Principle of Relativity, Dover Publ.

## Module:- AMATH 531

## DISCRETE MATHEMATICS, GRAPH THEORY AND NON-LINEAR DYNAMICS

**Group-A:**
**Discrete Mathematics:(20 marks)**

Propositional Logic: Propositional Equivalence; Predicates and Quantifiers; Method of Proof; Normal forms; Applications.

Pigeon-hole principle, Pascal triangle, Principle of inclusion and exclusion. Generating functions, Recurrence relation, Derangements; Ramsey number, Ramsey theorem.
Partially ordered sets. Lattices. Distributive and complete lattices. Dilworth's theorem on poset. Applications.

Switching Circuit: Minimization Problems. Clocks, Flip-flops.

**Group-B:**
**Graph Theory:(20 marks)**

**Basic Definitions:** Graph as a binary relation; Subgraphs, Operations on Graph; Matrix representations of Graph and Multigraph, Graph Isomorphism. Graphical collection.
**Distance:** Eccentricity, Radius, Diameter, Girth, Circumference;
**Connectivity:** Cutpoint, Bridge, Edge Connectivity, Vertex Connectivity, Separable graph, Bloch.
**Tree:** Spanning trees of a connected graph, Minimal Spanning Tree, Prim's algorithm. Linear spaces associated with graphs: Cycle subspace, Cutset subspace. Relation between bases and spanning trees.
**Graph colouring:** Chromatic number, Gurthrie's four colour problem(statement only).
**Planarity:** Crossing number, Kuratowski's theorem(statement only), Euler formula, Dual of a planar graph.
**Directed graph:** Orientation and Tournament, Strongly connectedness. Tournament and Irreducibility.
**Network flow:** Max-flow Min-cut theorem (statement only); Ford and Fulkerson algorithm.

**Group-C:**
**Non-Linear Dynamics:(10 Marks)**

**One Dimensional Flow:**
Flows on a line, Fixed Points and Stability. Examples. Bifurcation:Saddle-Node Bifurcation, Transcritical Bifurcation; Pitchfork Bifurcation. Examples.

**Two-Dimensional Flows:**
Classification of Linear Systems. Phase-plane, Existence, Uniqueness and Topological Consequences. Fixed Points and Linearization , Hyperbolic fixed points. Hartman-Grobman Theorem. Closed orbits, Limit Cycles , Poincaré – Bendixson Theorem. Examples.

**References:**


1. I.M.Copi, *Symbolic Logic*, Prentice Hall of India, 1979.
2. R. M.Martin, *Introducing Symbolic Logic*, Broadview Press Ltd, 2004.
3. R. Cori and D. Lascar, *Mathematical Logic*, Oxford University Press, 2000.
4. K.H. Rosen, *Discrete Mathematics and its Applications*, Tata McGraw Hill,7$^{th}$ Edit,2012.
5. C.L. Liu, *Elements of Discrete Mathematics*, McGraw Hill, 1985.
6. V.K. Balakrishnan, *Introductory Discrete Mathematics*, Dover Publications. Inc. Newyork, 1996.
7. J.Gallier, *Discrete Mathematics*, Springer, 2011.
8. Brualdi, *Introductory Combinatorics*, Pearson Education.Inc, 2008.

9. J.H.Van Lint & R.M.Wilson, *A Course in Combinatorics*, Cambridge University Press, 2001.
10. D.D.Givone, *Introduction to Switching Circuit Theory*, McGraw Hill, 1996.
11. N.S. Deo, *Graph Theory*, Prentice-Hall, New Delhi, 1994.
12. W.D. Wallis, *A Beginner's Guide to Graph Theory*, Birkhauser Boston($2^{nd}$ Ed.), 2007.
13. F. Harary, *Graph Theory*, Addison-Wesley, 1969.
14. B. Bollobas, *Modern Graph Theory*, Springer-Verlag New York, 2002.
15. S.H. Strogatz, *Non-linear Dynamics and Chaos,* Addison-Wesley Publ. Co., New York, 1994.
16. M.W. Hirsch, S. Smale and R.L. Devaney, *Differential Equations, Dynamical Systems and An Introduction to Chaos,* Elsevier Academic Press, 2nd Edition, 2004.
17. R.C. Hilborn, *Chaos and Non-linear Dynamics*, Oxford University Press, Oxford, 1994.
18. K.T. Alligood, T.D. Sauer and J.A. Yorke, *Chaos: An Introduction to Dynamical Systems*, Springer-Verlag, 1997.

## Module:- AMATH 532

## NUMERICAL ANALYSIS

**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.
**Eigenvalues and Eigenvectors of Real Matrix:** Power method for extreme eigenvalues and related eigenvectors, Jacobi's method for symmetric matrix, Given's and Householder's methods (Algorithms).
**Solution of Non-linear Equations:**
Single Equation - Aitken's $\delta^2$-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.
**Polynomial Interpolation:** Weirstrass's approximation theorem, Runge's phenomena, Divergence of sequences of interpolation polynomials for equi-spaced interpolation

points, piecewise polynomial interpolation Hermite interpolation, Error term, Cubic spline interpolation, Convergence properties, Inverse interpolation, Numerical differentiation using equi-spaced points.

**Approximation of Functions:** Least squares polynomial approximation, Approximation with orthogonal polynomials. Chebyshev polynomials, Lanczos economization, Harmonic analysis.

**Numerical Integration:** Problem of approximate quadrature, Round-off errors and Uniform coefficient formulae, Gauss-chebyshev quadrature, Euler-Maclaurin summation formula, Richardson extrapolation, Romberg integration, Double integrals - Cubature formula of Simpson Type, Improper integrals.

**Numerical Solution of Initial Value Problems:**

First Order ODE – Single step methods, RKF4 method, Multistep methods – Adams - Bashforth method, Adams - Moulton method, Milne's method, Convergence and stability.

Higher Order Equations -Runge-Kutta methods. Stiff differential equations.

**Numerical Solution of Boundary Value Problems:**

Two-point Boundary Value Problems for ODE - Finite difference methods. Passage method, Linear and nonlinear Shooting methods.

Ritz method, Galerkin method for boundary value problems.

Numerical Solution of PDE - Finite difference methods for (i) Parabolic type equation in one dimension (Heat equation) - Explicit finite difference method, Implicit Crank-Nicolson method, (ii) Hyperbolic type equation in one-space dimension (Wave Equation), (iii) Elliptic type equation; Method of characteristics (Consistency, Convergence and Stability).

**Numerical Solution of Integral Equations:** Volterra integral equation, Fredholm integral equation.

**References:**


1. A. Ralston, *A First Course in Numerical Analysis*, McGraw Hill, N. Y., 1965.

2. A. Ralston and P. Rabinowitz, *A First Course in Numerical Analysis*, McGraw Hill, N.Y, 1978.

3. S.D. Conte and C. DeBoor. *Elementary Numerical Analysis: An Algorithmic Approach*, McGraw Hill, N.Y., 1980.

4. K.E. Atkinson, *An Introduction to Numerical Analysis*, John Wiley and Sons, 1989

5. W.F. Ames, *Numerical Methods for PDES*, Academic Press, N.Y., 1977.

6. L. Colatz, *Functional Analysis and Numerical Mathematics*, Academic Press, N.Y, 1966.

7. C.T.H. Baker and C. Phillips, *The Numerical Solution of Nonlinear Problems*, C.P. Oxford, 1981

8. J.H. Ahlberg. E.N. Nilson and J.L. Walsh, *The Theory of Splines and Their Applications*, Academic Press, N.Y., 1967.

9. C.R. de Boor, *A Practical Guide to Splines*, Springer-Verlag, N.Y., 1978.

10. C.E. Fröberg. *Introduction to Numerical Analysis,* Addison-Wesley Publishing Company, 1969
11. R. Zurmuhl, *Numerical Analysis for Engineers and Physicists*, Allied Publishers Private Limited, Calcutta.
12. L. Fox, *Numerical Solution of Ordinary and Partial Differential Equations*, Oxford, 1962
13. P.M. Prentes, *Splines and Variational Methods*, Wiley-Interscience, N.Y.. 1975
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.

## Module:- AMATH 541

## NUMERICAL PRACTICAL

**Numerical solution of polynomial equations:** Bairstow's method, Q-D algorithm.

**Numerical solution of a system of equations:** Newton's method for a system of nonlinear equations.

**Computation for finding inverse matrix:** Gauss elimination method with partial pivoting, L-U decomposition due to Crout.

**Methods for Finding Eigen Pair of a Matrix**: Power method for least eigen value and corresponding eigen vector of a matrix. Rotation method of Jacobi for finding all eigen pairs of a matrix.

**Approximation:** Chebyshev Approximation, Minimax Approximation.

**Quadrature rule:** Romberg quadrature.

**Numerical Solution of IVP:** Single step methods - RKF-45 Scheme, Taylor series expansion method, Milne's starting formula, Multistep methods - Adams-Bashforth scheme, Adams-Moulton scheme, Milne's Predictor-Corrector formulae.

**Numerical solution of BVP:** Numerical solution for two point BVP - Passage method, Linear and nonlinear shooting methods.
Ritz method for approximate solution of BVP.
Finite difference method for PDE - Elliptic type PDE, Parabolic type PDE, Hyperbolic type PDE, Crank- Nicholson scheme for Parabolic type PDE.

**Numerical solution of Integral Equation:** Volterra type IE, Fredholm type IE.

## General Instructions:

Numerical problems are to be solved using (a) scientific calculator and (b) computer codes. Students will have to submit a report on their sessional works at the end of the semester. Use of advanced mathematical software for numerical computation will be encouraged.

# Module- AMATH 542

# STOCHASTIC PROCESS, DIFFERENTIAL EQUATION AND STABILITY

**Group-A:**
**Stochastic Process: (20 marks)**

Review of Probability: Sigma field; Probability measure. Random variables; Probability generating functions; Characteristic functions; Probability inequalities; Convergence concepts; random vectors; Bivariate and multivariate distributions.

Conditional Expectation: Conditioning on an event, conditioning on a discrete random variable, conditioning on an arbitrary random variable, conditioning on a sigma-field.

Martingales: Filterations, games of chance, stopping times, optional stopping theorem.

Markov chains: Definitions, Chapman-Kolmogorov equation, Equilibrium distributions, Classification of states, Long-time behaviour.

Stochastic process in continuous time: Poisson process and Brownian motion

**Group-B:**
**Stochastic Differential Equations: (20 Marks)**

Stochastic Calculus; Brownian motion, Wiener Process and white noise, Properties of Brownian paths and Langevin equation, Mean square Calculus, Definition and properties of Ito integral, Indefinite Ito integrals, Ito's formula, Simple examples, Concept of Stratonovich integral.

Stochastic differential equations; Definitions and examples; Linear stochastic differential equations and its solutions; Kolmogorov equation and Fokker-Planck equation of a stochastic differential equation.

**Group-C:**
**Stochastic Stability of Differential Equations: (10 Marks)**

Brief Review of Prerequisites from Probability Theory; Dissipative Systems of Differential Equations; Stochastic Processes as Solutions of Differential Equations; Boundedness in Probability of Stochastic Processes Defined by Systems of Differential Equations; Stability(stable in probability(Weakly), asymptotically stable in probability(Weakly), p-stable, Asymptotically p-stable, Exponentially p-stable, Almost surely stable); Stability of Randomly Perturbed Deterministic Systems; Estimation of a Certain Functional of a Gaussian Process ;Stability of Linear Systems .
Stationary and Periodic Solutions of Differential Equations. Stationary and Periodic Stochastic Processes; Convergence of Stochastic Processes; Existence Conditions for Stationary and Periodic Solutions; Special Existence Conditions for Stationary and Periodic Solutions; Conditions for Convergence to a Periodic Solution.

**References:**

1. W. Feller, An introduction to probability theory and its applications, John Wiley, New York , 1968.
2. J.L. Doob, Stochastic processes, John Wiley, New York, 1953.
3. M.S. Bartlett, An introduction to Stochastic Process, Cambridge University Press, 1955.
4. Z. Brzezniak and T. Zastawniak, Basic Stochastic Processes, Springer, Indian Reprint, 2005.
5. R. Coleman, Stochastic Processes, George Allen &Unwin Ltd., London , 1974.
6. L. Takacs, Science paperbacks and Methuen and Co. Ltd., London, 1966.
7. P.G. Hoel, S.C. Port and C.J. Stone, Introduction to Stochastic Processes, Universal Book Stall, New Delhi, 1993.
8. J. Medhi, Stochastic Processes, Wiley Eastern Ltd., New Delhi, 1983.
9. L. Arnold, Stochastic Differential Equations: Theory and Applications, Wiley, 1974.
10. L. Breiman, Probability, Addison-Wesley, 1968.
11. P. Bremaud, An Introduction to Probabilistic Modeling, Springer, 1988.
12. K.L. Chung, Elementary Probability Theory with Stochastic Processes, Springer, 1975.
13. A. Friedman, Stochastic Differential Equations and Applications, Vol. 1 & 2, Academic Press.
14.C.W. Gradiner, Handbook of Stochastic Methods for Physics, Chemistry and the Natural Sciences, Springer, 1983.
15.I.I. Gihman and A.V. Skorohod, Stochastic Differential Equations, Springer, 1972.
16. H. McKean, Stochastic Integrals, Academic Press, 1969.

17. E. Nelson, Dynamical Theories of Brownian Motion, Princeton University Press, 1967.
18. B.K. Oksendal, Stochastic Differential Equations: An Introduction with Applications, 4th ed., Springer, 1995.
19. D. Stroock, Probability Theory: An Analytic View, Cambridge University Press, 1993.
20. R.Khasminskii: Stochastic Stability of Differential Equations, Springer-Verlag Berlin Heidelberg 2012.

## Module:- AMATH 545

## INTEGRAL EQUATIONS & WAVELET TRANSFORMS AND PROJECT

**Group-A:**
**Integral Equations & Wavelet Transforms: (25 marks)**

**Integral Equations:**
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.

**Wavelet Transforms:**
Definition of wavelet, Examples, Window function, Windowed Fourier transform, Continuous wavelet transform, Discrete wavelet transform, Multiresolution analysis, Application to signal and image processing.

**Group-B:**
**Project: (25 Marks)**

**References:**

1. D. Porter and D.S.G. Stirling, Integral Equations, Cambridge University Press, 2004.
2. H. Hochstadt, Integral equations, Wiley-Interscience, 1989.
3. A. Wazwaz, A first course in integral equations, World Scientific, 1997.

4. F.G. Tricomi, Integral Equations, Dover, 1985.
5. Ram P. Kanwal, Linear Integral Equation – Theory and Technique, Academic Press, Inc.
6. W.V. Lovitt, Linear Integral Equations, Dover, New York.
7. S.G. Mikhlin, Integral Equations, Pergamon Press, Oxford.
8. N.I. Mushkhelishvili, Noordhoff, Singular Integral Equations, Gronignen, Holland.
9. W. Pogorzclski, Integral Equations and Their Application, Vol. I, Pergamon Press, Oxford.
10. R.M. Rao and A.S. Bopodikar, Wavelet Transforms Introduction to Theory and Application, Pearson Education Inc., 2006.
11. J. Benedetto and M.W. Frazier, Wavelets: Mathematics and Applications, C.R.C. Press, 1994.
12. C. Blatter, Wavelets. A Primer, A.K. Peter Ltd., 1998.
13. G. Buchman, L. Novice and E. Beckenstein, Fourier and Wavelet Analysis, Springer (Indian Reprint), 2005.
14. David F. Walnut, An Introduction to Wavelet Analysis, Birkhäuser, 2002.
15. Gilbert G. Walter and Xiaoping Shen, Wavelets and Other Orthogonal System, Chapman and Hall/CRC, 2001..
16. Eugenio Hernandez and Guido Weiss, A First Course on Wavelets, CRC Press, 1996.
17. Barbara Burke Hubbard, The World According to Wavelets, University Press, 2003.

# ADVANCED PAPERS FOR MODULES AMATH 533, AMATH 543 AND AMATH 544

## AMADV 5301

## BASICS OF QUANTUM MECHANICS

Inadequacy of classical mechanics, Superposition principle, Wave-Particle duality, Wave Formalism, The Schrödinger equation, probability, normalization, expectation value, coordinate and momentum representation.

Dirac Formalism, Bra-ket algebra and linear operators on Hilbert spaces. Foundational aspects: Postulates of quantum mechanics, brief introduction to quantum logic, Heisenberg's Uncertainty Relation, Bohr's Complementarity Principle.

Discrete and continuous spectrum. Stationary Schrodinger's Equation, free particle, typical one-dimensional problems: the potential step, reflection and transmission coefficients; the potential well and bound states; Delta-Function potential; the potential barrier and tunnelling. Linear harmonic oscillator.

Angular momentum operator: general formalism, matrix representation. Eigenvectors of Orbital angular momentum operator in spherical coordinate, properties of spherical harmonics. Spin angular momentum. Schrödinger equation in higher dimensions: Radial equation, Hydrogen atom, O(4) symmetry, degeneracy.

Approximation methods: Time independent perturbation theory, WKB method, Variational method; Stark and Zeeman Effect.

Time development of a quantum system, Time Dependent Potential, Heisenberg and Interaction Pictures, Transition Probability, Adiabatic and Sudden Approximations.

Identical Particles, Superselection rule, Slater Determinant and Pauli Exclusion Principle.

Scattering cross-section, Scattering amplitude, Born approximation. Partial wave analysis.

**References:**


1. P.A.M. Dirac, *The Principles of Quantum Mechanics*, International Science of Monographs, Oxford University Press, 1958.
2. E. Merzbacher, *Quantum Mechanics*, Wiley, New York, 1970.A. Messiah, Quantum Mechanics, North Holland, Amsterdam, 1968.
3. J.L. Polkinghorne, *The Quantum World*, Longman, London, 1984.
4. E.J. Squries, *The Mystery of the Quantum World*, Adam Hilger, Bristol, 1986.
5. B.H. Bransden and C.J. Joachain, *Introduction to Quantum Mechanics*, ELBS, 1990.
6. A. Das, *Lectures on Quantum Mechanics*, Hindustan Book Agency, New Delhi, 2003.
7. L.I. Schiff, *Quantum Mechanics*, McGraw Hill, New York, 1968.
8. R. Shankar, *Principles of Quantum Mechanics*, Plenum, New York, 1980.
9. S. Gasiorowiez, *Quantum Physics*, John Wiley & Sons, New York, 1995.

10. J.J. Sakurai, *Modern Quantum Mechanics*, $2^{nd}$ eds., Addison-Wesley, ISE Reprint, 1999.
11. W. Greiner and B. Müller, *Quantum Mechanics*, Springer-Verlag, 1989.
12. C. C. Tannoudji, B. Diu and F. Laloe, *Quantum Mechanics*, 2 Vols., Wiley-Interscience, 2006.
13. D.J. Griffiths, *Introduction to Quantum Mechanics*, $2^{nd}$ ed., Pearson Education, 2004.
14. L.E. Ballentine, *Quantum Mechanics*, World Sci. Publ., Singapore, 2001.
15. N. Zettili, *Quantum Mechanics*: Concepts and Applications, $2^{nd}$ Edition, John Wiley & Sons, 2009.
16. B. G. Englert, *Lectures on Quantum Mechanics*, Vol. 1 and 2, World Scientific Publ., 2006.

# AMADV 5401

# QUANTUM INFORMATION AND QUANTUM COMPUTATION

Resume of quantum mechanics; State vectors and Hilbert spaces, tensor product in finite dimensional spaces, no-cloning theorem, density operator, pure and mixed states, qubit system and Bloch sphere, superposition and mixtures. Measurements: the case of projective measurements, the case of POVM and its projective extension on a larger space. Evolution in quantum mechanics: unitary evolution for pure and mixed states. Schrödinger and von Neumann equations, adiabatic evolution, Kraus decomposition, CP maps and Quantum channels.

Quantum Information:
Theory of entanglement: Separability and inseparability, bipartite system, pure and mixed entangled states, Schmidt decomposition, Purification, EPR paradox, Hidden variables and Bell inequalities, Separability criteria, Partial transposition and PPT criteria, LOCC.

Distance measures, trace distance, fidelity, Shannon entropy, von-Neumann entropy and is properties (subadditivity, concavity, etc.)

Distinguishability of quantum states, accessible information, Holevo Bound, typical subspaces and quantum compression. Data compression and Schumacher's theorem. Classical and quantum information over noisy quantum channels. Applications of entanglement: quantum dense coding, quantum teleportation, entanglement swapping, quantum eraser and which way information. Entanglement distillation, dilution and error corrections.

Entanglement measures: Entropy of entanglement, concurrence, relative entropy of entanglement, entanglement of formation, entanglement cost and distillable entanglement, Logarithmic negativity. Entanglement in multipartite systems.

Quantum computation: Classical and quantum computers, circuit complexity, one- and two-qubit gates, circuit representation, controlled-NOT, universality, geometric gates, DiVincenzo criteria, Deutsch's algorithm, Grover's algorithm, Basics of Shor's algorithm, Quantum error correction, CSS codes, stabilizer code formalism, Clifford codes. Fault-tolerant quantum computation, Implementations of quantum computers, trapped ions, Josephson junctions.

Quantum cryptography: Basics of classical cryptography, Symmetric systems, one time pad, public key systems, RSA, limits of classical cryptography, quantum key distribution, BB84 and Ekert91 protocols, privacy and coherent information, experiments.

**References:**


1. M.A. Nielsen and I. Chuang : Quantum Computation and Quantum Information, Cambridge University Press, Cambridge, 2000.
2. J. Preskill, Lecture notes on Quantum Computation, Physic 219/Comp. Sc.219 Course, available in http://theory.caltech.edu/people/preskill/ph229.
3. J. Gruska : Quantum Computing, McGraw Hill Companies, 1999.
4. D. Bouwmeester, A. Ekart and A. Zeilinger (Eds.), *The Physics of Quantum Information*, Springer, New York, 2000.
5. G. Benenti, G. Casati and Giuliano Strini, *Principles of Quantum Computation and Information*, World Scientific, Singapore, 2004.
6. Asher Peres, *Quantum Theory : Concepts and Methods*, Kluwer Academic Publ., Dordrecht, 1995.
7. M. Redhead, Incompleteness, *Nonlocality and Realism*, Clarendon, Oxford University Press, 1987.
8. G. Alber et al., *Quantum Information*, Springer, Berlin, 2001.
9. W.H. Steeb and Yorick Hardy, *Problems and Solutions in Quantum Computing and Quantum Information*, World Scientific, Singapore, 2004.
10. H.K. Lo, S. Popescu and T. Spiller, *Introduction to Quantum Computation and Information*, World Scientific, Singapore, 1998.
11. M. Hayashi, *Quantum Information*, Springr Verlag, Berlin, 2006.
12. J.S. Bell, *Speakable and Unspeakable in Quantum Mechanics*, Cambridge University Press, Cambridge, 1988.
13. A.A. Grib and W.A. Rodrigues, Jr., *Nonlocality in Quantum Physics*, Kluwer Academic Publ., New York, 1999.

14. H.S. Leff, and Andrew F. Rex (eds.), *Maxwell's Demon 2*, Institute of Physics Publ., Bristol, 2003.
15. D. Bruss and G. Leuchs (eds.), *Lectures on Quantum Information*, Wiley-VCH, 2007.
16. A.Y. Kitaev, A.H. Shen and M.N. Vyalyi, *Classical and Quantum Computation*, American Mathematical Society, 2002.
17. Y. Hardy and W.H. Steeb, *Classical and Quantum Computing*, Birkhauser Basel, 2002.

## AMADV 5402

## QUANTUM FIELD THEORY

Relativistic Quantum Mechanics: Klein-Gordon equation, Difficulty with probability interpretation. Dirac equation, Properties of gamma-matrices, Free particle solution. Parity, Time-reversal and charge-conjugation in Dirac equation.

Field Quantization: Classical field theory, Lagrangian and Hamiltonian formalism of a particle in an electromagnetic field, Second quantization, Concepts and illustrations with Schrödinger field. Quantization of a real scalar field and its application to one meson exchange potential. Quantization of a complex scalar field, Dirac field and Electromagnetic field, Commutation relations.

Interaction: Yukawa interaction, coupling of electron and electromagnetic field, Global and gauge invariance.

Perturbation Theory: Scattering Matrix; Reduction Formalism; Wick's theorem.

Feynman diagrams, Feynman rules, Feynman graphs for Compton and e-e scattering,

Renormalisation: Divergences in Feynman integrals and Dimensional Regularisation.

Path Integral formulation of Quantum Mechanics, Generating functional, quantization of gauge fields, Ward –Takahashi Identities.

**References:**

1. C. Itzykson and I. Zuber, *Quantum Field Theory*, McGraw-Hill, 1980.
2. J.D. Bjorken and S.D. Drell, *Relativistic Quantum Fields*, McGraw-Hill, 1965.

3. L.H. Ryder, *Quantum Field Theory*, Academic Publishers, 1989.
4. N.N. Bogoliubov and D.V. Shirkov, *Introduction to the Theory of Quantised Fields*, Wiley, 1980.
5. C. Nash, *Relativistic Quantum Fields*, Academic Press, 1978.
6. P. Ramond, *Field Theory: A Modern Primer*, Benjamin/Cummings, 1981.
7. L.D. Faddeev and A.A. Slavnov, *Gauge Fields: Introduction to Quantum Theory*, Benjamin/Cummings, 1980.
8. A. Lahiri and P.B. Pal, *A first book of Quantum Field Theory*, Narosa, New Delhi, 2001.
9. J.J. Sakurai, *Advanced Quantum Mechanics*, Addison-Wesley, ISE Reprint, 1999.
10. Steven Weinberg, The *Quantum Theory of Fields, Vol. 1 and 2*, Cambridge University Publ., 2005.
11. A. Zee, *Quantum Field Theory in a Nutshell*, Princeton, 2010.
12. F. Mandl and G. Shaw, *Quantum Field Theory*, Wiley, 2010.

## AMADV 5302

## INCOMPRESSIBLE FLUID MOTION

**Flow through Mouthpieces:** External mouthpiece, Internal mouthpiece, Minor losses.
**Some incompressible flow patterns:** Pressure driven flow in a slot, Plane Couette flow, Rayleigh problem.
**Some Solutions of the Navier–Stokes Equations:** Stokes oscillating plate, Transient for a Stokes oscillating plate, Decay of ideal line vortex, Plane Stagnation Point Flow.
**Velocity and temperature fields** for (i) flow between two parallel plates, (ii) flow through circular pipe; Goaetz thermal entrance problem.
**Boundary Layers:** Blasius flow over a flat plate, Displacement thickness, Von Karman momentum integral, Von Karman – Pohlhausen approximate method, Falkner-Skan similarity solutions, Joukowski airfoil, Joukowski airfoil boundary layer, Axisymmetric boundary layers, Mangler's transformation, Flow past a wedge, Flow in convergent channel, Two-dimensional Jet, Axisymmetric jet, Blasius series solution method.

**Low-Reynolds-Number flow:** Stokes equations, uniqueness of the solution of the Stokes equations, Stokes flow over sphere, Non-uniformity of Stokes flow in infinite domain, Stokes flow near a circular cylinder, Oseen's equations.
**Lubrication Approximation:** Reynolds equation for bearing theory, Slipper pad bearing, Squeeze film lubrication: viscous adhesion, Hele-Shaw flow.

**References:**

1. H. Lamb, Hydrodynamics, Cambridge Univ. Press, 1932.
2. L. Prandtl, Essential of fluid dynamics, Springer, 2004.
3. F. M. White, Viscous Fluid Flow, McGraw Hill, 1991.
4. R. L. Panton, Incompressible Flow, John Wiley and Sons, 1984.
5. L. Rosenhead, Laminar Boundary Layer. Dover, 1988.
6. F. S. Sherman, Viscous Flow (McGraw Hill ).
7. S. I. Pai, Viscous Flow Theory, D. Van Nostrand, 1997.
8. H. Schlichting, Boundary Layer Theory, Springer, 2001.
9. L. Milne Thompson, Theoretical Aerodynamics. Dover, 1966.
10. L. M. Landau and E. M. Lifshitz, Fluid Mechanics, Butterworth Heinemann, 2005.

## AMADV 5403

## COMPRESSIBLE FLOW

Field equation of compressible flow
Crocco-Vazsonyl equation
Propagation of small disturbance in a gas
Dynamical similarity of two flows
Plane rotational and irrotational motion with supersonic velocity
Characteristics and their use for solution of plane irrotational problem
Prandtl-Mayer fluid flow past a convex corner
Steady linearized subsonic and supersonic flows. Prandtl-Glauret transformation
Flow along a wavy boundary
Flow past a slight corner
Jangen-Rayleigh method of approximation
Ackeret's formula Legendre and Molenbrock transformations
Chaplygin's equation for stream-function
Solution of Chaplygin's equation
Subsonic gas jet, limiting line
Motion due to a two dimensional source and a vortex
Karman-Tsien approximation
Transonic flow, Euler's-Tricomi equation
Hyperosnic flow

**References:**


1. P.A. Thompson. Compressible-fluid Dynamics. McGraw Hill Book Co.
2. A.H. Shaproo. Compressible Fluid Flow.
3. Oswatitsch. Gas dynamics.
4. Lipman Bers. Aspects of subsonic and transonic flows.


# AMADV 5404

# TURBULENCE

**1. Overview of the statistical problem**

What is turbulence? Definition and characteristic features;
The development of turbulence; Homogeneous, isotropic turbulence (HIT) ;
The turbulence problem in real flows ;
Formulation of the turbulence problem in HIT ;
The characteristics of HIT;
Renormalized perturbation theory (RPT): the general idea;
Primitive perturbation series of the Navier–Stokes equations;
Application to the closure problem: the response function;
Renormalization; Vertex renormalization;
Physical interpretation of renormalized perturbation theory;
Renormalization group (RG) and mode elimination;
RG as stirred hydrodynamics at low wavenumbers;
RG as iterative conditional averaging at high wavenumbers;

**2. Basic equations and definitions in x-space and k-space**

The Navier–Stokes equations in real space;
Correlations in **x**-space;
The two-point, two-time covariance of velocities;
Correlation functions and coefficients in isotropic turbulence;
Structure functions;
Basic equations in **k**-space: finite system;
The Navier–Stokes equations;
The symmetrized Navier–Stokes equation;
Moments: finite homogeneous system; Basic equations in **k**-space: infinite system; The Navier–Stokes equations; Moments: infinite homogeneous system; Isotropic system; Stationary and time-dependent systems; The viscous dissipation; Stirring forces and negative damping; Fourier transforms of isotropic correlations, structure functions, and spectra.

**3. Formulation of the statistical problem**

The covariance equations;
Off the time-diagonal: $C(k; t, t\_)$;
On the time diagonal: $C(k; t, t) \equiv C(k, t)$;
Conservation of energy in wavenumber space;
Equation for the energy spectrum: the Lin equation;

The effect of stirring forces;
Conservation properties of the transfer spectrum $T(k, t)$;
Symmetrized conservation identities; Alternative formulations of the triangle condition;
The Edwards $(k, j, \mu)$ formulation;
The Kraichnan $(k, j, l)$ formulation;
Conservation identities in the two formulations;
The $L$ coefficients of turbulence theory in the $(k, j, \mu)$ formulation;
Dimensions of relevant spectral quantities;
Finite system;
Infinite system; Some useful relationships involving the energy spectrum;
Conservation of energy in real space;
Viscous dissipation; Derivation of the K´arm´an–Howarth equation;
Various forms of the KHE;
The KHE for forced turbulence;
KHE specialized to the freely decaying and stationary cases

**4. Turbulence energy: its inertial transfer and dissipation**

The test problems ;
Test Problem 1: free decay of turbulence ;
Test problem 2: stationary turbulence ;
The Lin equation for the spectral energy balance ;
The stationary case;
The global energy balances ;
The local spectral energy balance;
The energy flux;Local spectral energy balances: stationary case;The limit of infinite Reynolds number; The peak value of the energy flux; Summary of expressions for rates of dissipation, decay, energy injection, and inertial transfer ; The K´arm´an–Howarth equation as an energy balance in real space; The Kolmogorov (1941) theory: K41; The '2/3' law: K41A ; The '4/5' law; The '2/3' law again: K41; The Kolmogorov (1962) theory: K62;Some aspects of the experimental picture; Spectra ; Structure functions;Is Kolmogorov's theory K41 or K62?

## References:


1. U. Frisch. Turbulence (Cambridge University Press).
2. S.I. Pai. Viscous Flow Theory (Turbulent Flow). (Princeton).
3. O.J. Hinze. Turbulence. (McGraw Hill).
4. Homogeneous, Isotropic Turbulence - Phenomenology, Renormalization and Statistical Closures---W. David McComb

# AMADV 5405

# COMPUTATIONAL FLUID DYNAMICS

Finite difference and finite volume description

Explicit and implicit scheme

Lax-Wendroff scheme for Hyperbolic, elliptic and parabolic equation

Basic concepts of CFD

Introduction to CFD code

Grid generation

Differential equation methods

Algebraic methods

Some simple applications to inviscid incompressible and compressible fluid.

**References:**


1. J.H. Ferziger. Computational Methods for Fluid Dynamics. (Springer).
2. A.W. Date. Introduction to Computational Fluid Dynamics (Cambridge).
3. Z.U.A. Warsi. Fluid Dynamics. Theoretical and Computational Approach. (Taylor and Francis).
4. Jean-Jacques Chattot. Computational Aerodynamics and Fluid Dynamics (Springer).
5. P. Niyogi, S.K. Chakraborty, M.K. Laha. Introduction to Computational Fluid Dynamics. (Pearson Education).


# AMADV 5303

# DYNAMICAL MODELS OF ECOLOGY

**Basic Concepts of Ecology:** Dynamical Models, Deterministic and Stochastic. State Variables, Discrete-Time and Continuous-Time Dynamical Models.

**Single-Species Population:** Discrete-Time Models, Difference Equations (linear and non-linear), Solutions, Cobweb Diagram, Steady states and criteria of stability, Population growth model, Discrete Logistic growth, Rabbit Problem and Fibonacci Sequence. Examples.

**Single-Species Population:** Continuous time model equation, Basic biological and mathematical assumptions, Malthus growth, Logistic growth, Gompertz growth, Harvest Model, Steady states and stability, Delay-Differential equation models, Linear analysis and stability. Examples.

**Interacting Population:** Lotka-Volterra Model of Predator-Prey System. Generalization of Lotka-Volterra Model. Periodic Solutions and Limit Cycle. Poincaré-Bendixson Theorem, Discrete Models. Lotka-Volterra Models of Competition and Mutualism. Cooperative System. Kolmogorov Model. Nature of Population Interaction. Examples.

**Stochastic Models of Population:** Stochastic differential equation. Connection with Fokker-Planck Equation. White noise Wiener Process, Coloured noise, Ornstein – Uhlenbeck Process. Stochastic Stability Applications in Population Dynamics.

**References:**


1. J.D. Murray, Mathematical Biology, Vol. I & II, Springer-Verlag, 2001.
2. M. Kot, Elements of Mathematical Ecology, Cambridge University Press, 2001.
3. H.I. Freedman, Deterministic Mathematical Models in Population Ecology Marcel Dekker, 1989.
4. F. Brauer and C. Castilo-Chavaz, Mathematical Models in Population Biology, Springer-Verlag, 2001.
5. T.C. Gard, Stochastic differential equation with application in population dynamics : Marcel-Dekker, 1987.
6. C.W. Gardiner, Stochastic Methods for Physics, Chemistry and Natural Sciences, Springer-Verlag, 1983.


## AMADV 5406

## DYNAMICS OF COMPLEX ECOLOGICAL SYSTEMS

**Complexity in Ecological Systems:** The Newtonian Paradigm in Physics, Dynamics and Thermodynamics, Emergent Properties, Ecosystems as Complex Adaptive Systems.

**Non-Linear Dynamics:** The Balance of Nature, Population Cycles, Catastropes and Breakpoints, Deterministic Chaos. Evidence of Bifurcation in Nature, Unpredictability and Forecasting, The Ecology of Universality, Criticism of Chaos, Complex Dynamics, The Interplay Between Noise and Non-Linearities.

**Spatial Self-Organization:** Space : The Missing Ingradient, Spatially Structured Population, Turing Instabilities, Coupled Map Lattice Models, Self-Organizing Spatial Pattern in Nature, Dispersal and Complex Dynamics.

**Scaling and Fractals in Ecology:** Scaling and Fractals, Fractal Time Series, Percolation, Non-equilibrium Phase-Transition, Ecological Multifractals, Complexity from Simplicity.

**References:**


1. R.V. Solé and J. Bascombte : Self-Organization in Complex Ecosystems. Princeton University Press (2006).
2. N. Boccara : Modelling Complex System, Springer-Verlag (2004).
3. J.D. Murray : Mathematical Biology, vol. I & II, Springer-Verlag (2001).


## AMADV 5407

## FRACTALS AND CHAOS

**Fractals:** Introduction, Countable and uncountable sets, Cantor set, Fractal properties of Cantor set, Dimension of self-similar fractals, Similarity dimension, More general sets, Box dimension, Pointwise and correlation dimensions, Multifracts, Examples.

**Chaos:** Introduction, Lorentz equations, Non-linearity, Symmetry, Volume contraction, Linear and global stabilities of the origin, Chaos on strange attractor, Exponential divergence of nearby trajectories, Formal definitions of chaos, Attractor and strange attractor, One-dimensional map, Fixed point and Cobwebs, Stability, Logistic map, Period-Doubling chaos and periodic windows. Liapunov Exponents. Examples.

**References:**


1. S.H. Strogatz, Non-liner Dynamics and Chaos. Addison-Wesley Publ. Co., New York, 1994.
2. P.S. Addison, Fractals and Chaos. Overseas Press, New Delhi (Indian Edition), 2005.

# AMADV 5408

# MATHEMATICAL MODELS IN PHYSIOLOGY AND MEDICINE

1. **Mathematical Models of Blood Flow:** Introduction, Basic Equation of Fluid Motion. Poisenille's law. Properties' of Blood, Poisenille's Law to the study of bifurcation in an artery. Pulsatile flow of blood. Analysis of blood flow using elastic theory. Pulse wave. Basic concepts of arterial blood flow.

2. **Mathematical models of Heat Physiology:** Basic concepts of heat and heart beat. The local model, the threshold effect. The phase-plane analysis and heart-beat model. Physiological consideration of heart beat cycle. A model of cardiac pacemaker.

3. **Mathematical Models of Nerve Impulse Transmission:** Basic concepts, phase-plane method. Qualitative behaviour of travelling wave. Global behaviour of nerve impulse transmission.

4. **Mathematical models in pharmacology:** Simple Drug Distribution Problems. Mathematical modelling in pharmacokinetics. Distribution of Metabolites in the body. Physiological application of two-compartment models. Mathematical modelling of Drug Effect.

5. **Mathematical models of diffusion in physiology:** The process of diffusion. Ficks' Law. Solution of diffusion equation. Diffusion through membrane. Diffusion in artificial kidney; absorption and diffusion of $\gamma$-Globulin in Lung Tissues. Oxygen diffusion through living tissues.

**References:**


1. J. Keener and J. Sneyd : Mathematical Physiology, Springer (1998).
2. J. Mazumder : An Introduction to Mathematical Physiology and Biology, Cambridge University Press (1989).
3. D.S. Jones and B. Sleeman : Differentiated Equation and Mathematical Biology. Allen and Unwin Publ., London (1983).
4. J.N. Kapur : Mathematical Models in Biology and Medicine, Afflicted East-West Press, New Delhi (1981).

# AMADV 5409

# ECONOPHYSICS

**Basic Information : Financial Markets**

Stock Markets and Derivatives. Three important derivatives – Forward contracts, Futures contracts and options.

**Binomial Tree Models**

Three ways to price a derivative; The Game Theory Method, Replicating Portfolios. The probabilistic approach. Risk. Repeated Binomial Trees and Arbitrage. A Stock Model Pricing a Call Option with tree Model. Adjusting Binomial Tree Model to Real World Data.

**Stochastic Calculus**

Mean Square Calculus, Ito Calculus, Brownian Motion, Wiener Process, Properties of Brownian Paths and Langevin Equation. Fokker-Planck Equation, Poisson Process.

**Continuous Models and Black-Scholes Formula**

A continuous time stock-model. The discrete model. Analysis of continuous model. Geometric Bownian Motion. Black-Scholes Formula. Black-Scholes differential equation, Finding portfolios, Solution of Black-Scholes equation and Interpretation Option Futures, Models Beyond Geometric Brownian Motion.

**References:**


1. J. Stampli and V. Goodman: The Mathematics of Finance, Thomson (2001).
2. W. Paul and J. Basehnagel: Stochastic Processes : From Physics to Finance. Springer (1999).
3. J. Voit: The Statistical Mechanics of Financial Markets : Springer (2001).
4. J.C. Paria: Stochastic Processes and Financial Markets. Narosa Pub. (2003).
5. R.N. Mantegna and HH.E. Stanley: An Introduction to Econophysics. Cambridge University Press (2006).

# AMADV 5304

# PLASMA KINETIC THEORY

Short range and long range forces; Some elementary ideas of electric and magnetic fields. Plasma as the fourth state of matter. Thermal ionization, Saha equation, Basic defining properties of plasma, Debye screening, Plasma parameter. Natural occurrence of Plasma. Applications of plasma physics.

Kinetic equations of plasma: Boltzmann equation (Noncollisional and collisional), BBGKY hierarchy equations, Vlasov equations.

Macroscopic Equation of Plasma: Two fluid description of plasma: charge, energy and momentum conservation equations.

Waves in Vlasov Plasma: Longitudinal and transverse waves in an unmagnetized plasma. Solution of initial value problem by Landau's method. Landau damping.

Vlasov theory of plasma instability: Two stream instability. Gentle-Bump instability. Penrose criteria of wave plasma instability with application.

Single fluid description of plasma: MHD equations, Generalized Ohm's law. Double adiabatic theory – CGL equations. Special cases. Energy integral.

**References:**


1. A.K. Nicholas and W.T. Alvin, Principles of Plasma Physics, McGraw Hill, Kogakusha, Ltd., Tokyo, New Delhi, etc. (1973).
2. J.A. Bittencourt, Fundamentals of Plasma Physics, Pergamon Press, Oxford-New York, Toronto, Sydney, Frankfurt (1986).
3. T.W. Stix, The theory of Plasma Waves, McGraw Hill Book Company, New York etc. (1962).
4. S. Chapman and T.G. Cowling, The mathematical Theory of Non-uniform Gases, Cambridge University Press (1970).
5. T.J.M. Boyd and J.J. Sanderson, Plasma Dynamics. Nelson, London.

# AMADV 5410

# FLUID PLASMA THEORY

Field of a moving point charge Radiated Power Lorentz Transformation of Electromagnetic field Intensities, Relativistic Motion of Charged Particles, Cerenkov Radiation and Gyroradiation.

Recapitulation of basic plasma properties.

Motion of charged particles in electric and magnetic fields: Larmor orbits, Particle drifts, Adiabatic invariants. Magnetic mirror. Motion of a charge particle in the field of a plane Electromagnetic wave.

Electromagnetic waves in dielectric medium: Propagation characteristics of waves; Dispersion Relation. Poynting Theorem, Wave Energy, Positive and negative energy waves.

Waves in warm unmagnetized plasma: Langmuir waves, Electromagnetic waves, Ion-acoustic waves.

Waves in cold homogeneous magnetoplasma: Dielectric tensor. Dispersion relation. Propagation along and perpendicular to the magnetic field. Cut-off and resonances. Refractive index surface. Alfvén Wave. Ion cyclotron wave, electron and ion whistler. Appleton-Hartee formula.

**References:**


1. F.F. Chen, Introduction to Plasma Physics, Plenum Press, New York and London (1977).
2. T.W. Stix, The Theory of Plasma Waves, McGraw Hill Book Company, New York, San Francisco, Toronto, London (1962).
3. S. Chapman and T.G. Cowling, The mathematical Theory of Nonuniform Gases, Cambridge University Press (1970).
4. T.J.M. Boyd and J.J. Sanderson, Plasma Dynamics, Nelson, London.
5. W.B. Thompson, An introduction to Plasma Physics, Pergamon Press, Oxford.
6. Hannes Alfven. ”Cosmic Plasma”. D. Reidel Publishing Company (1981).
7. L.C. Woods. “Principles of magnetoplasma dynamics”. Clarendon Press, Oxford (1987)

# AMADV 5411

# INSTABILITIES AND NONLINEAR PLASMA THEORY

**Transport Phenomena in Plasma:** Fokker-Planck's equation. Electrical conductivity. Free electron diffusion. Diffusion across a magnetic field. Ambipolar diffusion. Diffusion in a fully ionized plasma. Bohm diffusion.

**Plasma Confinement in a Magnetic Field:** Magnetic viscosity and Reynolds number. Diffusion of magnetic field lines. Frozen-in effect. Magnetic pressure. Plasma confinement in a magnetic field. Equilibrium pinch and dynamic pinch.

**Waves in Warm Magnetoplasma:** Propagation characteristics of Alfvén wave, magneto acoustic wave, CGL model, Firehose instability.

**MHD instabilities:** Normal mode and energy method. Interchange mode instability. Rayleigh Taylor instability, Sausage instability. Kink instability. Resistive Tearing instability.

**Nonlinear Plasma Theory and Parametric Oscillations in a Plasma:** Nonlinear wave propagation in a plasma. Concept of nonlinearity and dispersion. Ion acoustic soliton. Sagdeev potential. Reductive perturbation. KdV equation, its travelling wave solution. Pondermotive force. Caviton. Nonlinear Schrödinger equation. Envelope soliton.
Three wave interaction in plasma. Parametric instability. Stimulated Raman and Brilliouin instability in laser produced plasma.

**References:**


1. A.K. Nicholas and Alvin W. Trievelpiece, Principles of Plasma Physics, McGraw Hill Kogakusha, Ltd., Tokyo, New Delhi etc. (1973).

2. T.W. Stix, Theory of Plasma Waves, McGraw Hill Book Company, New York, San Francisco, etc. (1962).

3. R.C. Davidson, Methods in Nonlinear Plasma Theory, Academic Press, New York and London (1972).

4. A.B. Mikhailovskii, Theory of Plasma Instabilities, Vol. 1 : Instabilities of a homogeneous plasma; Vol.2 : Instabilities of an inhomogeneous plasma, Translated from Russian by: Julian B. Barbour, Consultants Bureau : New York, London (1974).

# AMADV 5305

# ADVANCED OPTIMIZATION AND OPERATIONS RESEARCH-I

**Revised Simplex Method:**
Product form of Inverse, RSM with and without artificial variables.

**Duality:**
Complementary slackness conditions, Primal – Dual algorithm.

**Post-optimal Analysis and Parametric Programming:**
Discrete changes in the cost vector, Discrete changes in the requirement vector, Discrete changes in the coefficient matrix, Addition of a variable, Addition of a constraint, Parameterization of the cost vector and the requirement vector.

**Large Scale Linear Programming : Special Computational Techniques:**
Composite Simplex Algorithm, Dantzig's Decomposition Algorithm, Upper bound constraints.

**Complexity of the Simplex Algorithm and Polynomial Algoritm:**
Polynomial complexity issues, computational complexity of the simplex algorighm, Khachian's ellipsoid algorithm, Karmarkar's projective algorithm.

**Queueing Theory:**
Poisson process and Exponential distribution, Markovian property of exponential distribution, single channel exponential queueing models, steady state solutions for M/M/1 model, Measure of effectiveness, Waiting time distributions, Finite system capacity queues with truncation M/M/1/K, Transient behaviour, Simple Markovian birth-death queuing models, Queues with parallel channels, Queues with parallel channels and truncations.

**Stochastic Inventory Models:**
Stochastic lot size models and their extensions, probabilistic models, safety and buffer stock, Concept of just-in-time inventory.

**Replacement Problems and System Reliability:**
Replacement of items that deteriorate with time, Replacement of items that fail completely, Other replacement problem, Basics of reliability, Classes of life distributions, Series, parallel, stand by configuration, Reliability models of maintained and non-maintained system. Renewal theory and its applications, Optimization problem with respect to system reliability.

**Geometric Programming:**
Polynomial, Geometric-arithmetic mean inequality, Unconstrained GPP, constrained GPP, complementary GP algorithm.

**References:**


1. Churchman, Ackoff, Arnoff, Introduction to Operations Research, John Wiley and Sons Inc., 1957.
2. Billy, E. Gillet, Introduction to Operations Research : A Computer Oriented Algirithmetic Approach, TMH Edition, 1979.
3. Beightler, Philips, Wilde, Foundations of Optimization, PHI, 1982.
4. Hillier, Lieberman, Introduction to Operations Research, McGraw Hill Book Company, 1989.
5. Ronald, V. Hartley, Operations Research – A Managerial Emphasis – Goodyear Publishing Company Inc., 1976, California.
6. Beveridge and Scheehter, Optimization Theory and Practice, McGraw Hill Kogakusha, Tokyo, 1970.
7. Gross and Harris, Queueing Theory, John Wiley.
8. Hadley G. and Whitham T.M. – Analysis of Inventory Systems, Prentice Hall, 1963.
9. Naddor E., Inventory systems, John Wiley, 1966.
10. Johnson L.A., Montgomery, Operations Research in Production Planning, Scheduling & Inventory Control, John Wiley, 1974.

# AMADV 5412

# ADVANCED OPTIMIZATION-II

**Optimization:**
The nature of optimization problem and scope of the theory.

**The non-linear programming problem and its fundamental ingredients:**
Linear inequalities and theorems of the alternative Farkas theorem. The optimality criteria of linear programming. Thucker's Lemma and existence theorems, Alternative theorems.

**Convex sets-separation theorems:**
Convex and Concave functions – Basic properties and some fundamental theorem for convex functions.

**Saddle point optimality criteria without differentiability:**
The minimization and the local minimization problems and some basic results. Sufficient optimality theorem, Fritz John saddlepoint necessary optimality theorem, Slater's and Karlinh's constraint qualifications and their equivalence, The strict constraint qualification, Kuhn-Tucker Saddle point necessary optimality theorems.

**Differentiable convex and concave functions:**
Some basic properties, twice differentiable convex and concave functions, theorems in cases of strict convexity and concavity of functions.

**Optimality Criteria with differentiability:**
Sufficient optimality theorem – Fritz-John stationary point necessary optimality theorem. The Arrow-Hurwicz-Zvawa constraint qualification, Kuhn-Tucker stationary-point necessary optimality theorem.

**Duality in non-linear programming:**
Weak duality theorem, Wolfe's duality theorem, strict converse duality theorem, Hanson-Huard strict converse duality theorem, Unbounded dual theorem, Duality in quadratic and linear programming.

**Unconstrained Optimization:**
Search Methods-Fibonacci search, Golden section search.
Gradient Methods- Method of steepest descent, Damped Newtown's Method, Davidson-Fletcher-Powell Method, Line search derivatives, Projection Methods.

**Constrained Optimization:**
Methods of feasible direction, Cutting hyperplane Method.

**References:**


1. Mangasarian O.L., Non-linear Programming, McGraw Hill, New York.
2. Mokhtar S. Bazara and C.M. Shetty, Non-linear Programming-Theory and Algorithms, Weiley, New York.
3. Mordecai Auriel, Non-linear Programming – Analysis and Methods, Prentice Hall Inc. Englewood Cliffs, New Jersey.
4. Kunzi H.P. – Non-linear Programming.
5. Rau John G, Optimization and Progability in Systems Engineering – Van Nostrand Reinhold Company, 1970.
6. Pfaffenberger R.C. and Walker D.A. – Mathematical Programming for Economics and Business – The IOWA University Press, IOWA, USA, 1976.
7. Satty T.L. – Mathematical Methods of Operational Research – Dover Publication Inc., New York, 1988.


## AMADV 5413

## ADVANCED OPERATIONS RESEARCH -II

**Network Analysis:**
Analysis of a project thorough network diagram, Network scheduling by CPM, PERT, Financial planning through network, Network crashing.
Network flow problems, Max-flow-min-cut theorem, Integral flow theorem, Maximum flow algorithms, Linear programming interpretation of Max-flow-min-cut theorem. The out-of-Kilter formulation of minimal cost network flow problem, Labeling procedure for the Out-of-Kilter algorithm, Insight into changes in Primal and Dual function values. Sequencing Problem.

**Stochastic Programming Problem:**
Stochastic programming, Uncertainty and certainty equivalence and passive approach to Stochastic Programming, Chance constrained optimization problem.

**Optimal Control Theory:**
Performance criterion, Unconstrained systems, Application of calculus of variation, constrained systems, Pontryagin’s principle, Quadratic performance criterion, Regulator problem.

**Matrix Game:**
Definition of a non-cooperative game. Admissible situation and the equilibrium situation, strategic equivalence of games. Antagonistic Games, Saddle points. Matrix Games. Mixed strategies. Existence of minimaxes in mixed strategies. Convex sets. The value of the game and optimal strategies.

**Continuous Games:**
Continuous games on unit square. Continuous game. Equilibrium Situation. Fundamental Theorem. Devices for Computing and Verifying Solutions.

**Differentiable Game:**
Two person deterministic continuous differential games, Two person zero-sum differential games, Pursuit games, Co-ordination differential games, Non-cooperative differential game.

**Simulation:**
Basic concepts, Monte Carlo method, Random number generation, Waiting the simulation model, New process planning through simulation, Capital budgeting through simulation.

**Information Theory:**
Shannon theory, Measure of information, Entropy – the expected information, Entropy as a measure of uncertainty, Memoryless channel, Conditional entropies, Mutual information, Information process by a channel, Channel capacity, Encoding, Shannon-Fanno encoding procedure.

**References:**


1. Joseph J. Madder, Cecil R, Philips, Project Management with PERT and CPM.
2. Panel A. Jensen, Wesley Barness J., Network flow programming, John Wiley and Sons, 1980.
3. Elmagharby Salah E., Activity Network Project Planning and Control by Network Models, John Wiley and Sons.
4. Fieneh S., Sequencing and Scheduling, Ellis Harwood Ltd., 1982.


## AMADV 5306

## ADVANCED COMPUTATIONAL METHODS-I

**Solutions of Polynomial Equations, Transcendental Equations and System of Equations:**

Kizner’s method, Newton-McAuley method, Tessler-Eisenberg method, Brent-Brown method, Laguerre’s method, Muller’s method, Broyden’s method, Computer implementation of the methods.

**Interpolation:**

Aitken-Neville iterated interpolation scheme, Periodic and non periodic splines, Cubic splines using first derivatives, Cubic splines using second derivative convergence theorem, Application of cubic splines.

**Matrix Inversion:**

Conventional inverse, Improvement of elements of inverse matrix by iterative scheme, Generalized inverse of a matrix, Operations on partitioned matrices, Inversion by partitioning, Computation of g-inverse by Gauss reduction type method, Application of generalized matrix inverses, Computer implementation of the methods.

**Eigen Value Problems:**

Eigen pairs of real non-symmetrical matrices, Computation of eigen values and eigen vectors by (i) Danilevsky method (ii) Krylov method.

**Optimization Techniques:**
One dimensional minimization methods – Fibonacci method, Golden section method.
Unconstrained optimisation techniques – Direct search methods, Steepest descent method, Quasi-Newton methods, Variable metric method (Daviddon-Fletcher-Powell method), Constrained optimisation techniques – Cutting plane method, Method of feasible directions.

**References:**

1. L. Collatz. Functional Analysis and Numerical Mathematics, Academic Press, N.Y., 1966.
2. K.E. Atkinson. An Introduction to Numerical Analysis, John Wiley & Sons (1989).
3. C.E. Fröberg. Introduction to Numerical Analysis, Addison-Wesley Pub. Co.
4. J.H. Wilkinson. The Algebraic Eigen Value Problem. Clarendon Press, Oxford (1965).
5. R. Zurmuhl. Numerical Analysis for Engineers and Physicists. Allied Pub. Pvt. Ltd., Calcutta.
6. M.H. Schultz. Spline Analysis, Prentice Hall, 1972.
7. B.P. Demidovich and I.A. Maron. Computational Mathematics, Mir Publishers, Moscow, 1976.
8. M.J. Maron. Numerical Analysis – A Practical Appraoch, McMillan Pub. Co., New York.
9. E. Bodewig. Matrix Calculus. Amsterdam, North Holland Pub. Co., 1959.
10. E.V. Krishnamurthy and S.K. Sen. Numerical Algorithms : Computations in Science and Engineering, New Delhi, Affiliated East-West Press, 1991.

11. H.M. Antia. Numerical Methods for Scientists and Engineers – McGraw Hill Pub. Co. Ltd., New Delhi, 1991.
12. S.S. Rao, Optimization Theory with Applications, New Age International (P) Pvt. Ltd.
13. C.R. Rao and S.K. Mitra, Generalized Inverse of Matrices and its Applications, Wiley, 1971.
14. R.M. Pringle and A.A. Rayner, Generalized Inverse Matrices with Application to Statistics, Hanfer Pub. Co., 1971.

# AMADV 5414

# ADVANCED COMPUTATIONAL METHODS-II

**Approximation:**

Linear approximation – Existence and uniqueness, Scalar product and scalar product spaces, Gramm determinant, Necessary and sufficient conditions of linear dependence of a set of elements of a scalar product space, Orthogonal set of elements, Best approximation in a Hilbert space and its construction, Fourier series and its convergence. Bessel's inequality and Parseval's equality – properties of orothogonal polynomials in real space $L_2$ (ω) on [a, b] and their zeros. Least squares approximations and error estimates. Factorial polynomials. Chebyshev Mini-Max approximation. Kolmogorov's criterion for a best approximation. Best approximation in space C. Haar's condition. Chebyshev theorem on necessary and sufficient condition for the characterization of the best approximation. Rational approximation. Continued fraction approximation. Padé approximation.

Spline function approximation to the solution of two point BVP for ODE. B-spline approximation.

**Simulation:**

Introduction, Methodology of simulation, Generation of random numbers, Monte-Carlo simulation, Simulation of different models, Advantages and limitations of simulation.

**Numerical Integration:**

Estimation of multiple integrals – (i) The method of reapplying quadrature formulae (ii) The Monte-Carlo method.

Approximation of singular integrals – Discontinuous integrands, Finite jump discontinuities. Infinite integrand, Infinite integration limits.

**Approximate Methods of Solving Integral Equations:**

Fredholm integral equation, Volterra integral equation. Spline function approximation to the solution of integral equation.

**Fast Fourier Transform:**

Discrete Fourier transforms and its basic properties. Fast Fourier Transforms (FFT), Computation of FFT, Fast Sine and Cosine Transforms, Some applications.

**Finite Element Method:**

Applications of FEM for ODE and PDE.

**References:**


1. E.W. Chenny. Introduction to Approximation Theory. McGraw Hill, N.Y., 1966.
2. N.I. Achieser (Translated by C.J. Hyman). Theory of Approximation, Frederick Ungar Publishing Co., N.Y., 1956.
3. P.J. Davis. Interpolation and Approximation, Blaisdell, N.Y., 1963.
4. P.M. Prenter. Splines and Variational Methods, Wiley-Interscience, N.Y., 1975.
5. M.J.D. Powell. Approximation Theory and Methods, CUP, 1981.
6. A.F. Timan. Theory of Approximation of Functions of Real Variable, Dover Pub., N.Y., 1994.
7. O.C. Zirenkiewicz. The Finite Element Method in Engineering Science – McGraw Hill, London, 1971.
8. G. Strang and G. Fix. An Analysis of the Finite Element Method, Prentice Hall, 1973.
9. G. Evans, J. Blackedge and P. Yardley. Numerical Methods for Partial Differential Equations, Springer, 2000.
10. J.S. Walker, Fast Fourier Transforms, CRC Press.


## AMADV 5415

## ADVANCED COMPUTATIONAL METHODS-III

**Numerical Solution of Differential Equations:**

General notion of consistency, convergence and stability. The Von Neumann stability test.

**Numerical Solution of Boundary Value and Eigenvalue Problems for ODE:**

Shooting methods, Multiple shooting methods, Direct methods, Finite difference methods, Error estimates, Order of convergence.

**Eigenvalue Problem:**

Difference method, Methods based on variational principles.

Computer realization of the methods.

**Numerical solution of PDE:**

Difference methods : Elliptic type equation : Laplace's equation in rectangles, Hyperbolic type equation : Wave equations and equivalent systems. Courant-Friedrichs-Lewy Condition (Domain of Dependence Condition).
Parabolic equation – Heat equation, Explicit and implicit difference schemes, Crank-Nicholson scheme.
Convergence of difference solutions to exact solution.

**Method of Characteristics:**

First order hyperbolic systems, convergence of difference solutions to the exact solution.

Semidiscrete methods for parabolic and hyperbolic PDEs.

Computer realization of the above methods.

**Numerical Solution for Stiff differential Equations:**

Stiff systems and absolute stability (A-stability), Example and Properties of A-stable methods. Certaine's method, Jain's method, V-levels Runge-Kutta methods, Rosenbrock methods for stiff problems. Numerical methods of boundary layer type.

**Ill posed problems:**

Selection method, Quasisolutions, Regularization methods, Regularizing operator, Methods of constructing regularizing operators, Examples of application of the regularization methods. Fredholm integral equation of first kind.

**References:**


1. J.H. Mathews. Numerical Methods for Mathematics, Science and Engineering, Prentice Hall of India Pvt. Ltd., 1994.
2. L. Fox. Numerical Solution of Ordinary and Partial Differential Equations. Oxford, 1962.
3. W.F. Ames. Numerical Methods for Partial Differential Equations, Academic Press, N.Y., 1977.
4. H.B. Keller. Numerical Methods for Two Point Boundary Value Problems, Blaisdell, Mass, 1968.
5. L. Fox. Numerical Solution of Two-point Boundary Problems, Clarendon Press, Oxford, 1957.
6. C.W. Gear. Numerical Initial Value Problems in Ordinary Differential Equations. Prentice Hall, 1971.
7. J.W. Thomas. Numerical Partial Differential Equations. Springer, 1995.
8. R.A. Willoughby (Ed.). Stiff Differential Systems, Plenum Press, N.Y., 1974.
9. W.L. Miranzer, D. Reidel. Numerical Methods for Stiff Equations and Singular Perturbation Problems, D. Reidel Publishing Co., Holland, 1981.
10. A.N. Tikhonov and V.Y. Arsenin. Solutions of ill-posed problems, 1977.


## AMADV 5307

## THEORY OF ELASTICITY I

**Formulation and Solution Strategies of Problems in Elasticity:** Review of field equations. Boundary conditions and fundamental problem classifications. Stress and displacement formulation. Other formulations. Saint-Venant’s principle. General solution strategies.

**Solution of Problem in Elasticity by Potentials:** The scalar and vector potentials for the displacements vector field. Equations of motion in terms of displacement potentials. Strain potential. Galerkin vector. Love’s strain function. Boussinesq’s problem. Neuber-Papkovich representation of solution.

**Two-dimensional Problems in Elasticity:** Plane state of strain, Plane state of stress and generalized plane stress and strain. Thick-walled tube under external and internal pressures. Rotating shaft. Stress function for plane stress problem. Airy’s stress function for two-dimensional problems. Fundamental biharmonic boundary-value problem.

**Complex Variable Methods:** Complex formulation of the plane elasticity problem. General solution of the biharmonic equation. Kolosoff-Muskhelisvili formulas. First and second boundary value problems in plane elasticity in terms of complex potentials. Structure of complex potentials in multi connected regions. Conformal mapping method: Integro-differential equations of Muskhelisvili and their solutions for simple problems.

**References:**


1. I. S. Sokolnikoff. *Mathematical Theory of Elasticity*. McGraw Hill, 1956.
2. A. E. H. Love. *A Treatise on Mathematical Theory of Elasticity*. Dover, 1954.
3. P.L. Gould. *Introduction to Linear Elasticity*. Springer-Verlog, 1994.
4. N. I. Muskhelisvili. *Some Basic Problems on the Theory of Elasticity*. Nordhoff, 1953.
5. Y. C. Fung. *Foundation of Solid Mechanics*. Prentice Hall, 1965.
6. L. D. Landau and E. M. Lifshitz. *Theory of Elasticity*. Pergamon Press, 1989.
7. S. Timoshenko and S. N. Goodier. *Theory of Elasticity*. McGraw Hill, 1970.
8. V. Z. Parton and P. I. Perlin. *Mathematical Methods of the Theory of Elasticity*. vol. I, II, Mir Publishers, 1984.
9. A. E. Green and W. Zerna. *Theoretical Elasticity*. Oxford: At the Clarendon Press.


# AMADV 5416

# THEORY OF ELASTICITY II

**Extension, Torsion and Flexure of Bars:** Bar stretched by its own weight. Torsion of a circular shaft. Torsion of bars of arbitrary cross-section: Dirichlet andNeumann problems. Prandtl’s stress function. Lines of shearing sheer. Torsion of bars with elliptic and triangular cross section. Flexure of beams by terminal loads. Centre of flexure. Simple problems. Membrane analogy.

**Strain Energy and Related Principles:** Strain-energy function. Clapeyron’s theorem. Uniqueness of the Elasticity boundary-value problems. Bounds on the elastic constants. Reciprocal theorem of Betti and Rayleigh. Principle of virtual work. Theorem of minimum potential energy and converse of the theorem. Theorem of minimum complementary energy. Theorem of minimum strain energy. Rayleigh-Ritz method.

**Elastic Waves:** Propagation of waves in an isotropic elastic medium. Waves of dilatation and distortion in isotropic elastic media. Helmholtz decomposition and displacement potentials. Body waves: P- SV- and SH- waves. Propagation of waves in an unbounded isotropic elastic solid. Wave propagation in two-dimensions. Plane waves. Reflection and refraction of elastic body waves. Surface waves: Rayleigh waves, Love waves.

**References:**


1. I. S. Sokolnikoff. *Mathematical Theory of Elasticity*. McGraw Hill, 1956.

2. A.E. H. Love. *A Treatise on Mathematical Theory of Elasticity*. Dover, 1954.
3. A.C. Eringen and E. S. Suhubi. *Elastodynamics: Vol. I and II*. Acaemic Press, 1974.
4. K.F. Graff. *Wave Motion in Elastic Solids*. Dover Publications Inc., N.Y., 1991.
5. H. Kolsky. *Stress waves in Solids*. Dover Publications Inc., N.Y., 1963.
6. J.D. Achenbach. *Wave Propagation in Elastic Solids*. North-Holland, N.Y., 1973.
7. A. Bedford and D.S. Drumheller. *Introduction to Elastic Wave Propagation*. John Wiley & Sons Ltd., Chichester, England, 1994.
8. W.M. Ewing, W.S. Jardetzky and F. Press. *Elastic Waves in Layered Media*. McGraw-Hill, N.Y., 1957.
9. Petter M. Shearen. Introduction to Seismology. Cambridge University Press, 1999.
10. J.D. Achenback. Wave propagation in elastic solids. North Holland Pub. Co., 1973.
11. K.E. Bullen and Bruce A. Bolt, An introduction to the theory of seismology, Cambridge University Press, 1987.
12. J. Prijol, Elastic wave propagation and genetic in seismology, Cambridge University Press, 2003.

## AMADV 5417

## THEORY OF ELASTICITY III

**Theory of Bending of Thin Plate:** Basic assumptions. Geometric relationships. Differential equation for bending of plates by transverse loads. Bending of circular, elliptical and rectangular plates under edge conditions.

**Vibration of Elastic Solids**: Torsional, longitudinal and flexural vibrations of a circular cylinder. Torsional and radial vibrations of a sphere. Flexural and extensional vibrations of a circular ring in a plane.

**Crack problems in linear elasticity:** Griffith crack, Penny-shaped crack. Strain energy associated with the crack. Stress intensity factor. Solution of some simple crack problems in solids with Griffith and Penny-shaped cracks. Crack propagation.

**Thermoelasticity:** Fundamental relations and equations of thermoelasticity. First and second law of thermodynamics. Principle of conservation of energy and entropy balance. The constitutive relations of thermoelasticity. Duhamel-Neumann relations. Coupling of strain and temperature fields. Time harmonic plane waves, transverse, longitudinal and transient waves in coupled thermoelasticity.

**Viscoelasticity:** Elementary concepts on viscoelasticity. Viscoelastic materials. Field equations in viscoelasticity. Kelvin-Voigt model and Maxwell model of viscoelasticity. Waves in an infinite medium and boundary value problem.

**References:**


1. S. P. Timoshenkoo and S.W. Krieger. *Theory of plates and shells*. McGraw-Hill International, 1984.
2. I. S. Sokolnikoff. *Mathematical Theory of Elasticity*. McGraw Hill, 1956.
3. A. E. H. Love. *A Treatise on Mathematical Theory of Elasticity*. Dover, 1954.
4. P.L. Gould. *Introduction to Linear Elasticity*. Springer-Verlog, N.Y., 1983.
5. I.N. Sneddon and M. Lowengurb. *Crack problems in the classical theory of elasticity*. John Wiley and Sons, Inc., 1969.
6. Ch. Zhang and D. Gross. *On Wave propagation in Elastic Solids with cracks.* Computational Mechanics Publications, 1998.
7. W. Nowacki. *Thermoelasticity*. Addison-Wesley Publishing Co., 1962.
8. J.L. Nowinski. *Theory of Thermoelasticity with Applications*. Sijthoff and Noardhaoff International Publishers, 1978.
9. A.C. Eringen and E.S. Suhubi. *Elastodynamics: Vol. I and II*. Acaemic Press, 1974.
10. R.S. Dhaliwal and A. Singh. *Dynamic Coupled Thermoelasticity*. Hindustan Publishing Corporation, 1986.


## AMADV 5308

## GEODESY AND GEOPHYSICS-I

Theory of elastic waves – Body waves and Surface waves

Reflection and Refraction of Seismic Waves. Dispersion of seismic wave energy and amplitude of seismic waves.

Ray Theory: Travel-time analysis.

Seismic evidences on the internal constitution of the earth.

Seismic Instruments: Study and Analysis of Records.

Geophysical Prospecting: Seismic Method.

**References:**


1. W. Lowrie, Fundamentals of Geophysics. Cambridge University Press.

2. K.E. Bullen and B.A. Bolt. An introduction to the Theory of Seismology, Cambridge University Press.
3. E. Savarensky. Seismic Waves, Mir Publishers.
4. J.B. Macelwane and F.W. Sohan. Introduction to Theoretical Seismology, John Wiley and Sons, N.Y.
5. W.M. Telford, L.P. Geldart, R.E. Sheriff and D.A. Keys. Applied Geophysics, Oxford and IBH Publishing Co. Pvt. Ltd.
6. R. Teisseyre (Ed.). Continuum Theories in Solid Earth Physics (Physics and Evolution of the Earth's Interior-3). Elsevier/PWN-Polish Scientific Publishers.
7. Markus Bäth. Mathematical Aspects of Seismology (Development of Solid Earth Geophysics-4). Elsevier Publishing Company.
8. B.V. Kostrov and Shamita Das. Principles of Earthquake Source Mechanics, Cambridge University Press.
9. W.M. Ewing and Others. Elastic Waves in Layed Media, McGraw Hill.
10. L.M. Brekhovskikh. Waves in Layed Media, Academic Press.
11. C.B. Officer. Introduction to Theoretical Geophysics. Springer-Verlag, N.Y.
12. K. Kasahara. Earthquake Mechanics. Cambridge University Press.
13. Tsuneji Rikitake. Earthquake Prediction, Elsevier-Scientific Publishing Company.
14. L.L. Nettleton, Geophysical Prospecting for Oil, McGraw Hill, N.Y.

## AMADV 5418

## GEODESY AND GEOPHYSICS-II

Figure of the Earth: Solid-Liquid Earth, Reference Ellipsoid, Geoid. Dimension of the reference ellipsoid from the measurement of meridian arcs. Geodesic.

Principle of Map Projection : General Principle. Normal Conical / Cylindrical Projection, Flamsteed Projection. Ideas of perspective projection. Photographic Projection.

Theory of Isostasy.

Geophysical Prospecting : Gravity Method.

Elements of Geomagnetism

Satellite Survey

**References:**


1. L.L. Nettleton, Geophysical Prospecting for Oil, McGraw Hill, N.Y.
2. V.L.S. Bhimasankaram. Exploration Geophysics, Association of Exploration Geophysics, Osmania University.
3. N. Sazina and N. Grushinsky. Gravity Prospecting, Mir Publishers.
4. G.L. Hosmer. Godesy, John Wiley and Sons.
5. H. Jeffreys. The Earth-Its Origin, History and Physical Constitution, Cambridge University Press.
6. G. Bomford. Geodesy, Oxford University Press.
7. A.A. Izotov. Foundation of Satellite Geodesy.


## AMADV 5419

## GEODESY AND GEOPHYSICS-III

Source Mechanism and Faulting: Lamb's problem. Representation Theorem. Haskel's Matrix Method. Method of Steepest Descent, Cagniard Method Seismic Trimography. Inverse Problem.

Theory of Continental Drift and Plat Tectonics.

Earthquake Intensity and Magnitude.

Microseism, Tsunami.

Geophysical Prospecting : Magnetic / Electromagnetic Method.

Earthquake Prediction Program. Designing of Earthquake Resistance Structure.

**References:**


1. W. Lowrie, Fundamentals of Geophysics. Cambridge University Press.
2. K.E. Bullen and B.A. Bolt. An introduction to the Theory of Seismology, Cambridge University Press.
3. E. Savarensky. Seismic Waves, Mir Publishers.
4. J.B. Macelwane and F.W. Sohan. Introduction to Theoretical Seismology, John Wiley and Sons, N.Y.
5. W.M. Telford, L.P. Geldart, R.E. Sheriff and D.A. Keys. Applied Geophysics, Oxford and IBH Publishing Co. Pvt. Ltd.
6. R. Teisseyre (Ed.). Continuum Theories in Solid Earth Physics (Physics and Evolution of the Earth's Interior-3). Elsevier/PWN-Polish Scientific Publishers.
7. Markus Bäth. Mathematical Aspects of Seismology (Development of Solid Earth Geophysics-4). Elsevier Publishing Company.
8. B.V. Kostrov and Shamita Das. Principles of Earthquake Source Mechanics, Cambridge University Press.
9. W.M. Ewing and Others. Elastic Waves in Layed Media, McGraw Hill.
10. L.M. Brekhovskikh. Waves in Layed Media, Academic Press.
11. C.B. Officer. Introduction to Theoretical Geophysics. Springer-Verlag, N.Y.
12. K. Kasahara. Earthquake Mechanics. Cambridge University Press.
13. Tsuneji Rikitake. Earthquake Prediction, Elsevier-Scientific Publishing Company.
14. L.L. Nettleton, Geophysical Prospecting for Oil, McGraw Hill, N.Y

# AMADV 5309

# DYNAMICAL METEOROLOGY

Equations of motion in various coordinates, The complete system of equations, Geostrophic, Gradient, Cyclostrophic and Thermal Winds. Geostrophic balance. Cyclostrophic and Inertial Flow.

Shallow water equations. β-plane approximation, Rotational and gravity waves. Hough functions, Equatorial waves, Circulation, Divergence and Convergence, Vorticity equation, Pressure tendency, Fronts, Classifications. Cyclones and Anti-cyclones.

Waves in atmosphere : Characteristics and classifications. Free Rossby Waves : Orographic and Thermal. Acoustic waves. Lamb mode. Kelvin waves. Rossby gravity model. Group velocity.

Quasi-geostrophic equations. Derivation. The omega equation. Filtering of gravity waves. Geostrophic adjustment.

Barstropic instability. The two-level model.

Sources and sinks of energy. Atmospheric energy balance.

**References:**

1. S.L. Hess, Introduction to Theoretical Meteorology, Holt, New York, 1959.
2. J.R. Holton, An introduction to Dynamic Meteorology, Elsevier, 2004.
3. A.E. Gill, Atmosphere Ocean Dynamics, Academic Press, 1982.

# AMADV 5420

# ATMOSPHERIC THERMODYNAMICS

Composition and structure of the atmosphere. Heat budget, Greenhouse effect, Classical thermodynamics. Review of basic concepts : internal energy and work, laws of thermodynamics, dry adiabatic process, entropy. Water substance. Phase change, Moist air thermodynamics : saturation, Clausisu-Clapeyron equation, humidity variables, saturated adiabatic processes, Equation of states for dry and moist air. Virtual temperature. Potential temperature. Equivalent potential temperature. Adiabatic and pseudo-adiabatic changes. Dew point, Thermodynamic chart, Thermodynamic diagrams. Properties of an ideal thermodynamic diagram. Different thermodynamic diagrams- their properties and significance.

Nucleation of drops and ice crystals. Formation of show and rain. Electrification. Storm clouds.

Mixing in the atmosphere : Horizontal mixing, vertical mixing, mixing condensation level.

Atmosphere stability : parcel method, stability indices, entrainment, conditional instability.

**References:**

1. J.V. Iribarne and V. Godson, Atmospheric Thermodynamics. Reidel Pub, 1973.
2. A.A. Tsonis, An Introduction to Atmospheric Thermodynamics, Cambridge University Press, 2002.
3. C.F. Bohren and B.A. Albrecht, Atmospheric Thermodynamics, Oxford University Press, 1998.
4. J.M. Wallace and P.V. Hobbs, Atmospheric Science : An Introductory Survey, Academic Press, 1977.
5. J.A. Curry and P.J. Webstar, Thermodynamics of Atmosphere and Oceans, Academic Press, 1999.
6. S.L. Hess, Introduction to Theoretical Meteorology, Holt, New York, 1959.

# AMADV 5421

# METEOROLOGICAL FORECASTING AND ANALYSIS

Introduction to weather forecasting. Scale analysis of atmospheric circulations. Types of meteorological observations. Modern observing systems. Weather satellites in forecasting : radiation basics, platform types, imagery types. Example of satellite image interpretation.

Radiative forcing. General atmosphere and oceanic circulation, Thermal wind and jet stream development.

High impact weather systems. Rossby wave trains. Interaction with Rossby waves.

Monsoon Meteorology. Indian context. Jet streak dynamics. CISK, ITCZ, Synoptic elements of monsoon system. El Nino.

Turbulent motion. Eddy Viscosity. Sea and Land Breeze temperature.

Severe thunderstorms. Environmental characteristics and mechanisms of initiation. Dry lines, Cold fronts aloft, Multi-cell versus supercell. Storm splitting, Mesoscale convective complex, Squall lines, Mesoscale forecasting.

**References:**


1. G.J. Haltiner, Numerical Weather Prediction, Wiley, New York, 1971.
2. H.B. Bluestein, Synoptic-Dynamic Meteorology in Midlatitudes, vols. I & II, Oxford University Press, 1992.
3. T. Palmer and R. Hagedorn, Predictability of Weather and Climate, Cambridge University Press, 2006.
4. J.M. Wallace and P. Hobbs, Atmospheric Science: An introductory survey, Academic Press, 1977.
5. J.V. Iribarne and V. Godson, Atmospheric Thermodynamics, Reidel Pub., 1978.
6. W. Saucier, Principles of Meteorological Analysis, Dover Publications, 2003.

# AMADV 5422

# DYNAMICAL OCEANOGRAPHY

**Properties of ocean water:** Temperature, salinity and density of ocean water, Density and specific volume as functions of temperature, salinity and pressure.
**Stability and double diffusion:** Criterion for static stability, Buoyancy frequency, Double diffusion, Dynamic stability.
**Basic equations of the ocean water:** Gibbs' relation, Equation of conservation of mass, Equations of motion, Equation of conservation of energy, Equation of evolution of potential vorticity.
**Approximations:** Boussinesq's approximation, β-plane approximation, Linearization of basic equations.
**Wave motion in the ocean:** Problem of free oscillations in ocean water, Laplace's tidal equations, Short wavelength waves, gyroscopic waves, internal waves, plane waves in rotating stratified ocean, Long wavelength waves, long wave equations in a continuously stratified fluid, the pressure equation, vertical mode for constant stratification, long gravity waves, Rossby waves.
**Currents without friction; Geostrophic flow:** Hydrostatic equilibrium, Inertial motion, Geopotential, Geopotential surfaces and isobaric surfaces, Relations between geopotential and isobaric surfaces, Geostrophic equation, The 'thermal wind' equations, Deriving absolute velocities, The beta spiral.
**Currents with friction; Wind-driven circulation:** Nansen's qualitative argument, Equation of motion with friction included, Ekman's solution, Ekman mass transport equations, Ekman pumping, Limitations of the Ekman theory, Sverdrup's solution for the wind-driven circulation, Munk's solution.
**Internal waves:** Interfacial waves in a two-layer ocean, Internal waves when the density varies continuously with depth, Normal modes for internal waves, Causes of internal waves, Simple model of thermocline.
**Some nonlinear waves:** Solitary waves, Uniform Stokes' waves.

**References:**


1. V. M. Kamenkovich, Fundamentals of ocean dynamics, Elsevier, 1977
2. P. Pond and G. Pickard, Introductory dynamical oceanography, Pergamon Press, 1986
3. J. Pedlosky, Geophysical fluid dynamics, Springer Verlag. 1979,
4. A. E. Gill. Atmosphere-Ocean Dynamics, Academic Press, 1982
5. A. S. Monin, Theoretical geophysical fluid dynamics, Kluwer Academic Publication, 1990,
6. L. A. Mysak and P. H. LeBlond, Waves in the ocean, Elsevier.
7. C. C. Mei, The Applied Dynamics of Ocean Surface Waves, Singapore: World Scientific, 1989.

# AMADV 5310

# DYNAMICAL SYSTEM I

**Continuous Dynamical Systems:**

Dynamical system: flow: existence and uniqueness; local and global solution.

Canonical form of linear system of O.D.E.; hyperbolic flow; contraction; generic properties.

Gronwall's inequality; continuity w.r.t. initial conditions.

Stability: asymptotic stability; Lyapunov function; Lyapunov's theorems.

Planar dynamical system; fixed points and their nature; phase space analysis.

Poincare-Bendixon's theory; Closed orbits. Bendixon's criterion, Closed orbits Volterra-Lotka system: Competing speciesInvariant set; attractor; □- and □-limit cycles; basins of attraction.

**Discrete dynamical systems:**

**1D Maps:** iterative maps; orbits; fixed and periodic points; periodic and eventually periodic orbits, graphical analysis; phase portraits; Stability of fixed points and periodic points, analysis of orbits of one dimensional maps; logistic map; quadratic family of maps, tent map. Sensitive dependence on initial conditions, Limit sets,

Schwarzian Derivative, negative Schwarzian derivative; Singer's theorem.

**2D Maps:** fixed points and periodic points; Stability of fixed points and periodic points; analysis of henon map, baker's map; other examples, Matrix times circle equal to ellipse, counting the periodic orbits of linear maps on a torus.

**Topological properties of one-dimensional maps :** Definition of Chaos,

Homeomorphisms and diffeomorphisms ;topological conjugacy and semi-conjugacy of maps. Periodic points; Dense sets, Bernoulli shift and topological transitivity; Definitions of deterministic chaos; Devaney chaos ;Sensitivity and Wiggins chaos ; Ljapunov chaos, horseshoe map & chaotic orbits. Period three implies chaos (with Proof), Sarkovskii 's Theorem (with Proof).

**Probabilistic description of one-dimensional maps :**

Dynamics of statistical ensembles, the Frobenius-Perron equation, Markov partitions and transition matrices; measure-theoretic description of dynamics;

probability measures; Basics of ergodic theory; invariant measure of piecewise linear maps, tent map, logistic map.

**Lyapunov Exponent**: Lyapunov number and Lyapunov exponent of 1D maps; Lyapunov numbers and Lyapunov exponents of 2D maps.

Connection between flow and maps; Poincaré map; connection between stability of Poincare maps and corresponding flows.

**References:**

1. M.W. Hirsch, S. Smale and R.L. Devaney, Differential Equations, Dynamical Systems and An Introduction to Chaos, Elsevier Academic Press, 2nd Edition, 2004.

2. R.L. Devaney, An Introduction to Chaotic Dynamical System, Addison-Wesley, 1989.

3. P.O. Drazin, Nonlinear Systems, Cambridge Univ. Press, 1993.

4. K.T. Alligood, T.D. Sauer and J.A. Yorke, Chaos: An Introduction to Dynamical Systems, Springer-Verlag, 1997.

5. V.I. Arnold, Ordinary Differential Equations, M.I.T. Press, Cambridge, 1973.

6. S.H. Strogatz, Nonlinear Dynamics and Chaos, Addison Wesley, 1994.

7. S.N. Rasband, Chaotic Dynamics and Nonlinear Systems, John Wiley & Sons, N.

8. Clark Robinson, Dynamical Systems: Stability, Symbolic Dynamics and Chaos, CRC Press, 1999.

## AMADV 5423

## DYNAMICAL SYSTEM II

Renormalization and universality of one dimensional smooth maps.

Invariant set, Invariant Cantor Sets for the Quadratic Family of maps; The Invariant Cantor Set for logistic map with $\mu > 4$; : properties of logistic map for parameter value $> 2 + \sqrt{5}$; Symbolic Dynamics for the quadratic Map.

Elements of nonlinear analysis :

Nemytskii operators; Implicit function theorem ;Applications of the implicit function theorem ;

Lyapunov-Schmidt reduction ; Floquet theory ; Poincare return maps; Center manifolds ;Normal forms;

Manifolds and transversality; Sard's theorem; Exercises.

**Local bifurcations**

The saddle-node bifurcation; One dimensional saddle-node bifurcation;Higher dimensional saddle-node bifurcation ;. Saddle-node bifurcation of periodic orbits ; The Hopf bifurcation ; The planar Hopf bifurcation ;

Higher dimensional Hopf bifurcation ; The period-doubling bifurcation ;The Bogdanov-Takens bifurcation ;

Exercises

**Nonlocal bifurcations**

Homoclinic loop; Shil'nikov homoclinic loop ; Blue sky catastrophe ;Homoclinic tangencies; Exercises .

**Structural stability and bifurcation**

Hyperbolicity and Peixoto's theorem;The Hartman-Grobman theorem;The Smale horseshoe and the Arnold cat map; Stability theorems; Global aspects of bifurcations ; Exercises.

**References:**

1. M.W. Hirsch, S. Smale and R.L. Devaney, Differential Equations, Dynamical Systems and An Introduction to Chaos, Elsevier Academic Press, 2nd Edition, 2004.

2. R.L. Devaney, An Introduction to Chaotic Dynamical System, Addison-Wesley, 1989.

3. D.K. Arrowsmith, Introduction to Dynamical Systems, Cambridge Univ. Press, 1990.

4. P.O. Drazin, Nonlinear Systems, Cambridge Univ. Press, 1993.

5. P. Glendinning, Stability, Instability and Chaos, Cambridge Univ. Press, 1994.

6. Clark Robinson, Dynamical Systems: Stability, Symbolic Dynamics and Chaos, CRC Press, 1999.

7. K.T. Alligood, T.D. Sauer and J.A. Yorke, Chaos: An Introduction to Dynamical Systems, Springer, 1997.

8. V.I. Arnold, Ordinary Differential Equations, M.I.T. Press,

# AMADV 5424

# DYNAMICAL SYSTEM III

Circle map: rotation number; two dimensional maps; Lyapunov exponents: dynamics of linear maps: hyperbolic toral automorphism: chaos on a torus: Morse-Smale diffeomorphism.

Henon map; standard map; twist map; area preserving maps: invertible maps: dynamics of a bouncing ball on a vibrating plane.

Smale horseshoe map: Smale-Birkhoff homoclinic theorem : Melnikov's method: damped forced pendulum: damped forced Duffing oscillator : Onset of chaos.

Hamiltonian System: perturbation theory: Kolmorov-Arnold-Moser theorem (Statement only) adiabatic invariance of action variable; KAM torus: irrational winding number and KAM stability; breaking of KAM tori.

Two dimensional attractors: solenoid attractor: Henon attractor: attractor of Lorenz type.

Dimension of an attractor: Fractal set : box dimension.

**References:**


1. M.W. Hirsch, S. Smale and R.L. Devaney, Differential Equations, Dynamical Systems and An Introduction to Chaos, Elsevier Academic Press, 2nd Edition, 2004.
2. R.L. Devaney, An Introduction to Chaotic Dynamical System, Addison-Wesley, 1989.
3. D.K. Arrowsmith, Introduction to Dynamical Systems, Cambridge Univ. Press, 1990.
4. P.O. Drazin, Nonlinear Systems, Cambridge Univ. Press, 1993.
5. P. Glendinning, Stability, Instability and Chaos, Cambridge Univ. Press, 1994.
6. Clark Robinson, Dynamical Systems: Stability, Symbolic Dynamics and Chaos, CRC Press, 1999.
7. K.T. Alligood, T.D. Sauer and J.A. Yorke, Chaos: An Introduction to Dynamical Systems, Springer, 1997.
8. V.I. Arnold, Ordinary Differential Equations, M.I.T. Press, Cambridge, 1973.
9. S.H. Strogatz, Nonlinear Dynamics and Chaos, Addison Wesley, 1994.
10. S.N. Rasband, Chaotic Dynamics and Nonlinear Systems, John Wiley & Sons, N.Y., 1989.
11. J. Guckenheimer and P. Holmes, Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields, Springer-Verlag, 1983.
12. Lichtenberg and Lieberman, Regular and Stochastic Motion, Springer Verlag, 1983.

13. J. Marsden and M. McCracken, The Hopf Bifurcation and Its Applications, Springer-Verlag, 1976.
14. G. Iooss and D.D. Joseph, Elementary Stability and Bifurcation Theory, Springer Verlag, 1997.
15. B.D. Hassard, N.D. Kazarinoff and Y-H Wan, Theory and Applications of Hopf Bifurcations, Cambridge University Press, 1981.
16. V.I. Arnold (Ed.), Dynamical Systems III, Springer, 1993.
17. Morse and Feshbach, Methods of Theoretical Physics, Part I, McGraw Hill, Kogaknsha, 1953.

# AMADV 5311

# GENERAL RELATIVITY

## Principles of General Relativity:

Riemannian curvature, Curvature tensor, properties of curvature tensor, Ricci tensor, ricci scalar, Bianchi's identity.
Symmetry of Riemannian spaces, Killing vector, Homogeneity & isotropy, Curvature of maximally symmetric spaces.
Non-inertial frames, principle of equivalence, principle of general covariance, free particle in curved space time, energy momentum tensor,.
Einstein field equations, Schwarzschild exterior solution, Birkoff's theorem, singularities in Schwarzschild space time, Schwarzschild interior solution.

## Applications of General Relativity:

Advance of perihelion of mercury, bending of light, Gravitational red shifts, Basic ideas of gravitational waves.
Schwarzschild solution: deviation and basic features, particle and photon orbits in Schwarzschild metric, Observational tests of general relativity.

## Standard theory of cosmology:

Simplifying assumptions of cosmology, the cosmological principle, Expansion of the Universe and redshift, Friedmann-Robertson-Walker models (closed, flat and open Universe), critical density, FRW solutions for simple equations of state of cosmic matter and radiation.
Cosmological constant, de sitter Universe.

## Early Universe:

Big bang model, Thermodynamics and thermal history of early universe, baryogenesis, Nucleosynthesis, relic neutrinos and microwave background radiation, Recent observational results.

## Inflation:

Problems of the standard cosmological model: Flatness (or fine tuning), Horizon, Monopole Resolution with an inflated (accelerated expansion): Cosmological Constant: The de Sitter Universe: Scalar fields giving rise to inflation (inflaton) : Problems of inflation – graceful exit etc. Various methods to overcome them: extended inflation, slow roll etc.

## Dark Energy:

Type IA supernova as standard candles. Luminosity-Redshift relation – dimming of the brightness of the supernovae: Resolution: a negative deceleration parameter q – an accelerated expansion : Agents driving acceleration – dark energy. The best candidate – Cosmological constant ($\Lambda$CDM model). Problems with $\Lambda$ -discrepancy between the predicted and the observed values : Quintessence models: Qualitative description of the agreement of a presently accelerating universe with other observations – BAO, CMB, Hubble data etc.

## References:


1. J.V. Narlikar, Introduction to Cosmology, Cambridge University Press.
2. T.Padmanavan, Theoretical Astrophysics, vols 1-3, Cambridge University Press.
3. Sriranjan Banerjee & Asit Banerjee, General Relativity and Cosmology, Elsevier.
4. Ronald Adler, Maurice Bazin & Menahem Schiffer , Introduction to General Relativity, McGraw Hill.
5. S.Weinberg, Gravitation and cosmology, Wiley.
6. *Bernard* F. Schutz , A First Course in General Relativity (second edition), Cambridge University Press **.**
7. James B. Hartle, Gravity: An Introduction to Einstein's General Relativity.
8. Albert Einstein, The Principle of Relativity, Dover Publications.


# AMADV 5425

# GRAVITATION AND BLACK HOLES

### Exact solutions of Einstein field equations:

Minkowski space-time; De Sitter space-time, Robertson-Walker spaces; the solution of the vacuum-field equations, General discussion of the Schwarzschild solution, Isotropic coordinates.

### Black holes and Stellar collapse:

Characterization of coordinates, Singularities, Space-time diagram in Schwarzschild coordinates, Kruskal coordinates, Event horizons, Black holes – a classical arguments, Observational evidence for black holes; Stellar collapse.

**Cosmological Principle:**

Newtonian cosmology, the red shift, the Einstein universe, the expanding universe, Simplifying assumptions of cosmology, Weyl's postulate, the Cosmological principle, Observational background, Hubble's law, Observable parameters in Robertson-Walker models, Cosmological red shift, Apparent brightness, Angular size, Source counts, Olbers Paradox.

**References:**


1. S.W. Hawkins and G.F.R. Ellis, The Large-Scale Structure of Space-time, Cambridge University Press, 1989.
2. S. Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, Wiley, N.Y., 1972.
3. C.W. Misner, K.S. Thorne and J.A. Wheeler, Gravitation, Freeman, San Francisco, 1973.
4. J.V. Narlikar, Introduction to Cosmology, Cambridge Univ. Press, 2002.
5. J.V. Narlikar, Lectures on Gravitation and Cosmology.


# AMADV 5426

# COSMOLOGY

**The Friedmann Models:**

Einstein field equations simplified for cosmology, Energy tensors of the universe, Random motions in an expanding universe, Dust models, Radiation models, Cosmologies with a non-zero cosmological constant, Space-time singularity, Luminosity distance in different models, Horizons and the Hubble radius; the Particle horizons, the Event Horizon, the Angular size-redshift relation.

**Bigbang Cosmology :**

The radiation dominated universe, thermodynamics of the early universe, the microwave background, the standard models, early epochs of the universe, cosmological coincidences, the steady-state theory, inflation, the anthropic principle; the horizon problems, flatness problem, entropy problem and the monopole problem in Friedmann cosmology.

**Formation of large scale structure in the universe :**

The Jeans mass in the expanding universe, the evolution of the Jeans mass, Growth in the post-recombination era, growth in radiation-dominated universes.

**References:**


1. S.W. Hawkins and G.F.R. Ellis, The Large-Scale Structure of Space-time, Cambridge University Press, 1989.
2. S. Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, Wiley, N.Y., 1972.
3. C.W. Misner, K.S. Thorne and J.A. Wheeler, Gravitation, Freeman, San Francisco, 1973.
4. J.L. Synge, Relativity: The General Theory, North Holland, Amsterdam, 1960.
5. J.V. Narlikar, Introduction to Cosmology, Cambridge Univ. Press, 2002.
6. J.V. Narlikar, Lectures on Gravitation and Cosmology.


# AMADV 5427

# ASTROPHYSICS AND RELATED DATA ANALYSIS

**Basic Background:**

Elementary radiative transfer equations , absorption and emission, atomic processes, continuum and line emission , Telescopes, distance measurements, Hubble's law.

**The Sun:**
General features of different regions of sun, sources of solar energy, sun spots and solar cycles, solar wind, solar neutrino puzzle, planets and other objects of solar systems.

**Spectral Classifications of Stars :**
Saha's equation, Absolute and apparent magnitudes, Mass luminosity relation, Hertsprung-Russell diagram.

**Stellar structure :**

Equations for hydrostatic equilibrium, Virial theorem, basic Thermodynamics, polytropic stars, Lane Emden equations and its solutions.

**Evolution of stars:**

Formation of protostars and stars, Evolution of low and high mass stars, Thermonuclear reactions, Supernova, formation of heavy elements.

**Cold compact objects:**

Degenerate electron gas, White dwarf, Chandrasekhar limit, Neutron stars, Maximum mass of neutron star, Blackhole.

**Binary Stars :**

Different types of binary stars, Importance of binary systems, Accretion and gravitational radiation (basic ideas).

**Galaxies:**

Formation and classification, Density wave theory of the formation of spiral arms, Rotation curves, Missing mass and dark matter, Quasars and active galactic nuclei, Our Galaxy, Oort's constants, magnetic field.

**Elementary data analysis:**

Regression problem related to various scaling relations of Astronomical objects. Dimension reduction and clustering problems related to multidimensional data.

**Hands on (non credited) :**

1. Solar Limb darkening experiment.
2. Studying the radiation pattern of various antennas in the radio frequency range at 750 MHz.
3. Calculations in General Relativity using symbolic tensor package GRTENSOR.
4. Different multivariate data analytic techniques in astrophysics using Software packages (Skymap Pro-11, TopCat, DS9, sdss dr13 Tutorials, SQL Data retrieval & R-latest version).

**REFERENCES:**


1. K.D. Abhyankar, Astrophysics, Stars and Galaxies , University Press.
2. Arnab Rai Choudhuri, Astrophysics for Physicists, Cambridge University Press.
3. B.Basu, T.Chattopadhyay & S.N.Biswas, An Introduction to Astrophysics, Prentice Hall of India.
4. Steven Phillipps, The Structure & Evolution of Galaxies, Wiley.
5. Keith Holliday, Introductory Astronomy, Wiley.

6. S. Chandrasekhar, An Introduction to the Study of Stellar structure, Dover Publications.
7. Keith M. Ashman & Stephen E. Zepf, Glbular Cluster Systems, Cambridge University Press.
8. Josef Kallrath & Eugene F.Milone, Eclipsing Binary Stars: Modeling and Analysis, Springer.
9. Lee Hartmann, Accretion Processes in Star Formation, Cambridge University Press.
10. Daniel W. Weedman, Quasar Astronomy, Cambridge University Press.

## AMADV 5312

## ALGORITHMS AND DATA STRUCTURE

**Programming Principles:** Introduction to Computer Programming – Object-Oriented, Functional, Logic. Concepts on abstraction mechanism using C, C++ and Java. Abstract Data Type.

**Analysis of Algorithms:** Complexity measures, worst-case and average-case complexity function. Problem complexity.

**Data Structure:** Introduction, formal definition, implementation of basic data structures – Arrays, Lists, Linked Lists, Stacks, Queues, Dequeue, Priority Queue, Recursions, Trees and Graphs.

**Sorting and Searching:** Sorting techniques with complexity analyses – Insertion, Selection, Merging, Radix Sort, Quick Sort, Heap Sort, etc. Sequential search, Binary search, Indexed sequential search.

**Trees:** Binary trees, Traversals of binary trees, Threaded binary trees, Binary search trees, AVL tress, B-trees.

**Hashing:** Basic ingredients, Analysis of hashing with chaining and with open addressing.

**References:**

1. E. Horowitz and S. Sahni, Fundamentals of Data Structures, Galgotia Booksource, New Delhi, 1983.
2. R.L. Kruse, B.P. Leung and C.L. Tondo, Data Structures and Program Design in C, Prentice Hall of India, 1999.
3. Y. Langsam, M.J. Augestein and A.M. Tanenbaum, Data Structures using C and

C++, Prentice hall of India, 2000.

4. R. Elmasri and S.B. Navathe, Fundamentals of Database System, Addison Wesley Publ. Co., 1994.
5. D.E. Knuth, The Art of Computer Programming, Vol. 1-5, Addison Wesley, 1997.

# AMADV 5428

# THEORY OF AUTOMATA

**Sequential Machine without Output:**

Introduction, response functions, accessible states and connected machines, the free automation, congruence relations and homomorphisms. Quotient machines.

**Sequential Machines with Output:**

The behaviour of sequential machines, behavioural equivalence, Mealy machine, Moore machine.

**The Minimization Problem:**

The minimal machine having a given behaviour, relations on the set of states, algorithm for computing the minimal machine.

**Finite Automata:**

Deterministic and non-deterministic automata. Equivalence and minimization of finite automata.

**Transition system:**

Transition systems and regular expressions, the subset construction, the language of regular expressions, the analysis and synthesis theorems, applications of the analysis and synthesis theorems.

**Hardware Realization and the State-assignment Problem:**

Hardware realization, decomposition of machines.

**Probabilistic Machines:**

Probabilistic machines, the behaviour of probabilistic machines.

**Grammar and Languages:**

Derivations, Language generated by a grammar. Regular language and regular grammars. Pumping Lemma. Context-free and context-sensitive grammars and languages.

**Turing Machine:**

Basic definitions. Turing machine as language acceptors. Universal Turing machine.

**References:**


1. J.E.Hopcroft,R.Motwani,J.D.Ulman, Introduction to automata theory,Languages and Computation,Dorling Kindersly (India) Pvt.Ltd, 2008.
2. S. Ginsberg, An introduction to Mathematical Machine Theory, Addison-Wesley, 1964.
3. J. Hartmanis and R.E. Stearns, Algebraic Structure Theory of Sequential Machines, Prntice-Hall,1966.
4. L. Taylor.Booth, Sequential Machines and Automata theory, John Wiley and Sons,1968.
5. D. Kelly, Automata and Formal Languages: An Introduction, Prentice- Hall, 1995.
6. Peter Linz, An Introduction to Formal Languages and Automata, Jones & Bartlett Learning LLC, 2017.
7. Z. Kohavi, Switching and Finite Automata Theory, Tata McGraw-Hill, 2008.
8. J.A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006.
9. J.E.Hopcroft and J.D. Ulman, Formal Languages and Their Relation to Automata, Addision-Wesley, 2009.
10. Martin J.C. Introduction to Languages and The Theory of Computation, Tata McGraw Hill, 2009.
11. Mark V. Lawson, Finite Automata, CRC Press, 2004.
12. H.R.Lewis and C.H.Papadimitriou, Elements of The Theory of Computation,Prentice- Hall, 2010.
13. M.Simon, Automata Theory,World Scientific Publishing Co.Pvt.Ltd, 2001.
14. M.Davis, Computability and Unsolvability ,Dover Publications,Inc.Newyork, 1985.
15. A.Paz,Introduction to Probabilistic Automata, Academic Press, 1971.

# AMADV 5429

# DATABASE MANAGEMENT SYSTEMS, GRAPH THEORY AND COMBINATORICS

**Database Management System:**

Overview of file organization technique : Sequential, direct, indexed, hashed, inverted, B-Trees.

Data Models : Relational, Network, Hierarchical.

Relational Model – Algebra, Calculus, Normal forms, Implementation of query languages, Security and protection of data recovery methods.

Concurrent Operations on Databases : Introduction to distributed database system. Case Studies.

**Graph Theory and Combinatorics:**

Matrix representation of graphs : incidence matrix, adjacency matrix, circuit matrix, main properties and their applications in various graph theoretic problems. Algorithms to determine a path from adjacency and incidence matrices. Algorithms for identifying shortest spanning trees from incidence and adjacency matrices. Dijkstras algorithm to locate shortest path from a given distance matrix of a directed graph. Network flow problem and its graph theoretic solution. Ford and Fulkerson algorithm for maximum flow from a given adjacency matrix.

Equivalence relation on a set induced by a permutation group on the set. Burnside's theorem on counting of equivalence classes. Equivalence relation on the set of functions from a domain D to a range R. Weight of a function. Polya's theorem on counting the equivalence classes of functions. Applications of Polya's theorem to various problems on counting. Counting of non-isomorphic graphs using Polya's theorem. Pigeonhole principle and its generalization Ramsey's theorem and its applications. Determination of Ramsey numbers. Simple applications.

**References:**


1. E. Horowitz and S. Sahni, Fundamentals of Data Structures, Galgotia Booksource, New Delhi, 1983.
2. R.L. Kruse, B.P. Leung and C.L. Tondo, Data Structures and Program Design in C, Prentice Hall of India, 1999.
3. Y. Langsam, M.J. Augestein and A.M. Tanenbaum, Data Structures using C and $C^{++}$, Prentice hall of India, 2000.

4. R. Elmasri and S.B. Navathe, Fundamentals of Database System, Addison Wesley Publ. Co., 1994.
5. D.E. Knuth, The Art of Computer Programming, Vol. 1-5, Addison Wesley, 1997.
6. H.F. Korth and A. Silberschatz, Database Concepts, $2^{nd}$ Edition, McGraw Hill, 1991.
7. J.D. Ullman, Principles of Database and Knowledge Base System. Vol. I & II, Computer Science Press, 1988.
8. J.E. Hopcroft and J.D. Ulman, Introduction to automata theory, languages and computation (Addison-Wesley).
9. N. Deo, Graph Theory with applications to Engineering and Computer Science, Prentice Hall of India, $11^{th}$ Printing, 1995.
10. C.L. Liu, Introduction to Combinatorial Mathematics, McGraw Hill Book Company, 1968.
11. V. Chachra, P.M. Ghare and J.M. Moore, Applications of Graph Theory Algorithms, North Holland, 1979.
12. B. Kolman, R.C. Busby, S.C. Ross and N. Rehman, Discrete Mathematical Structures, Pearson Education, 2006.
13. J. Riordan, An Introduction to Combinatorial Analysis, John Wiley and Sons, 1958.
14. H.J. Ryser, Combinatorial Mathematics, John Wiley and Sons, 1963.

## AMADV 5430

## ASTROSTATISTICS

Basic Background: Elementary radiative transfer equations, absorption and emission, atomic processes. Distance measurement in Astronomy. Hubble's law

Spectral Classification of Stars: Saha's equation, Harvard System, Luminosity effects, Absolute and apparent magnitude, Mass luminosity relation, Spectroscopic parallax.

Evolution of Stars: Observational basis, Sources of stellar energy, Hertzsprung-Russell diagram, evolution of low and high mass stars, Chandrasekhar limit, Pulsars, neutron stars and black holes.

Stellar Populations- Galactic and Globular Clusters, Initial Mass Function (IMF)

Galaxies: Our Galaxy , External galaxies, Clusters of galaxies.

Application of Linear and Nonlinear Regression to various scaling relations for astrophysical objects e.g., Fundamental plane or relations among rotational measures for globular clusters.

Application of Stepwise Regression for extracting significant parameters in many parameter case in Astrophysical situation .

Study of Initial Stellar Mass Functions (IMF) through Monte Carlo Simulation.

Study of variable stars through Time Series Analysis.

Application of Principal Component Analysis.

Classification and Clustering, Discriminant Analysis, Factor Analysis for galaxies and globular clusters.

**Hands on:**

Applications of Astrophysical Problems through R, sdss, Aladin, Vizier.

**References:**


1. K.D. Abhyankar, Astrophysics, Stars and Galaxies , University Press.
2. Arnab Rai Choudhuri, Astrophysics for Physicists, Cambridge University Press.
3. B.Basu, T.Chattopadhyay & S.N.Biswas, An Introduction to Astrophysics, Prentice Hall of India.
4. Steven Phillipps, The Structure & Evolution of Galaxies, Wiley.
5. Keith Holliday, Introductory Astronomy, Wiley.
6. S. Chandrasekhar, An Introduction to the Study of Stellar structure, Dover Publications.
7. Keith M. Ashman & Stephen E. Zepf, Globular Cluster Systems, Cambridge University Press.
8. Josef Kallrath & Eugene F.Milone, Eclipsing Binary Stars: Modeling and Analysis, Springer.

9. Lee Hartmann, Accretion Processes in Star Formation, Cambridge University Press.
10. Daniel W. Weedman, Quasar Astronomy, Cambridge University Press.
11. Richard A. Johnson and Dean W. Wichern , Applied Multivariate Statistical Analysis, PHI
12. Chattopadhyay A. and Chattopadhyay T : Statistical Methods for Astronomical Data Analysis, Springer.

## ANNEXURE- I

****Choice Based Credit Course A/B** (Full Marks : 50 Marks)

# Some Methods in Applied Mathematics

**Gr-A : Differential equations: (30 Marks = 20 + 10)**

**(i) Ordinary Differential Equation: (20)**

Linear homogeneous differential equation: Ordinary and singular points, Series solution. Linear non-homogeneous differential equation: Solution by variation of parameters, Strum -Liouville's equation. Eigen value problem. Green's function. Legendre function. Rodrigues formula. Orthogonal property. Recurrence relations. Bessel function. Orthogonal property. Recurrence relations. Hypergeometric function.

One Dimensional Flow**:** Flows on a line, Fixed Points and Stability. Examples.
Bifurcations: Saddle-Node Bifurcation, Transcritical Bifurcation; Pitchfork Bifurcation. Examples.
Two-Dimensional Flows: Classification of Linear Systems. Phase-plane, Existence Uniqueness of solutions and its Topological Consequences. Fixed Points and Linearization , Hyperbolic & non-hyperbolic fixed points. Hartman-Grobman Theorem.

**(ii) Partial Differential Equation: (10)**

Classification of second order partial differential equations. Solution of Three Fundamental equations: Laplace equation, Wave equation and Diffusion equation. Concept of nonlinearity and wave breaking. Solution of Burger and KdV equations.

**Gr-B : Numercal Analysis: (20 Marks)**

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

**Numerical Solution of System of Linear Equations:** Triangular factorisation methods, Matrix inversion method, Operation counts, Iterative methods – Convergence condition of Gauss-Seidel method and Gauss-Jacobi method, Importance of diagonal dominance. Least square solution.

**Solution of Non-linear Equations:** Modified Newton-Raphson method (for real roots-simple or repeated). Roots of Real Polynomial Equations: Sensitivity of polynomial roots, Bairstow's method of quadratic factors. Non-Linear Systems of Equations: Newton's method.

**Numerical Integration:** Newton-Cotes formulae, Gauss-Legendre and Gauss-chebyshev quadratures. Romberg integration, Simpson's adaptive quadrature, Fredholm integral equation. Improper integrals.

**Introduction to Numerical Solution of differential equation:** Runge-Kutta methods for first order IVP-ODE. Multistep methods – Adams-Bashforth method and Adams-Moulton method. Finite Difference Methods (FDM) for two-point BVP. Finite Difference Methods (FDM) for PDE. Numerical solution of one-dimensional Heat equation and Wave Equation through explicit and implicit FDM.

**References:**

1. E.A. Coddington and N. Levison, *Theory of Ordinary Differential Equations*, Tata McGraw Hill, 1955.
2. E.L. Ince, *Ordinary Differential Equations*, Dover, 1956.
3. N.N. Labedev, *Special Functions, and their applications*, Dover, 1972.
4. I.N. Sneddon, *Special functions of Mathematical Physics and Chemistry*, Longman, 1980.
5. R. Courant and D. Hilbert, *Methods of Mathematical Physics (2 Vols.)*, Wiley, New York, 1966.

6. Lawrence C. Evans, *Partial Differential Equations, Second Edition*, American Mathematical Society, 2014.
7. I.N. Sneddon, *Elements Of Partial Differential Equations*, McGraw Hill, 1986.
8. E. Zauderer, *Partial Differential Equations of Applied Mathematics*, A Wiley-Interscience Publication, John Wiley and Sons, 1983.
9. C.R. Chester, *Techniques in Partial Differential Equations*, McGraw Hill, New York, 1971.
10. K.S. Rao, *Introduction to Partial Differential Equations*, Prentice Hall, New Delhi, 1997.
11. S.D. Conte and C.R de Boor, *Elementary Numerical Analysis: An Algorithmic Approach*, McGraw Hill, N.Y., 1980.
12. K.E. Atkinson, *An Introduction to Numerical Analysis*, John Wiley and Sons, 1989.
13. W.F. Ames, *Numerical Methods for PDEs*, Academic Press, N.Y., 1977.
14. C.T.H. Baker and C. Phillips, *The Numerical Solution of Nonlinear Problems*, C.P.Oxford, 1981.
15. C.E. Fröberg, *Introduction to Numerical Analysis*, Addison-Wesley Publishing Company, 1969.
16. R. Zurmuhl, *Numerical Analysis for Engineers and Physicists*, Allied Publishers Private Limited, Calcutta.
17. L. Fox, *Numerical Solution of Ordinary and Partial Differential Equations*, Oxford, 1962.
18. C. Pozrikidis, *Numerical Computation in Science and Engineering*, Oxford University Press, Inc., N.Y., 1998.

****This module is offered by the Department of Applied Mathematics as one CBCC module paper for the master degree students of other disciplines of the University of Calcutta.**