Ph.D LEVEL COURSES FROM DEPARTMENT OF MATHEMATICS

MA801 FUZZY LOGIC AND NEURAL NETWORKS 4-0-0-4

Classical sets & Fuzzy sets- Crisp sets- an overview, Fuzzy sets-Basic types and concepts; Fuzzy sets versus Crisp sets – Additional properties of □ cuts – Representations of Fuzzy sets – Extension principles of Fuzzy sets; Operations on Fuzzy sets – Types of operations – Fuzzy complements – Fuzzy intersections-norms – Fuzzy unions: t-Conorms – Combinations of operations – Aggregation operations.
Fuzzy logic – Classical logic – Multivalued logic – Fuzzy propositions – Fuzzy quantifiers – Linguistic hedges – Interference from conditional fuzzy propositions, conditional and qualified propositions and quantified propositions; Uncertainty-based information – Information and uncertainty – non specificity of crisp sets – non specificity of fuzzy sets – fuzziness of fuzzy sets – uncertainty in evidence theory – Principles of uncertainty.
Fuzzy systems; Pattern recognition; Engineering Applications- Civil, Mechanical, Industrial, and Computer Engineering, and Reliability theory and Robotics.
Fundamentals of Artificial Neural Networks- Perceptrons – Back propagation – Counter propagation networks – statistical methods – Hopfield nets – Bidirectional Associative Memories – Optical Neural networks – cognitron and Neocognitron – Neuro-fuzzy controllers

TEXT BOOKS/ REFERENCES:

1. George J. Klir and Bo Yuan, "*Fuzzy Sets and Fuzzy Logic- Theory and Applications*", Prentice Hall of India, 1997.
2. Timothy J. Ross, "*Fuzzy Logic with Engineering Applications*", McGraw Hill, 1997.
3. H.J. Zimmermann, "Fuzzy Sets and its Applications", Allied publishers, 1991.
4. Wasserman, P. D, "*Neural Computing: Theory and Practice*", Van Nostrand Reinhold, New York, 1989.

MA802 PROBABILITY AND APPLIED STATISTICS 3-1-0-4

Random Variable and Distributions: Probability – random variable – discrete and continuous distribution functions – marginal and joint distributions – functions and transformation of random variables - mathematical expectations – moment generating functions and characteristic functions – standard distribution functions and applications.
Multivariate Random Variables: Bivariate and multivariate random variables and distributions-variance and covariance matrix – correlation - regression lines and curves - confidence interval for regression – tests for simple correlation and regression coefficients – rank correlation test.
Theory of Estimation: Population and – sampling distributions – central limit theorem – determination of sample size – t, F and Chi-square distributions – theory of estimation – point and interval estimation methods – Bayesian methods of estimation.
Hypothesis Testing and Statistical Quality Control: Testing of hypothesis – type-I and type-I errors and critical region – Normal, t, F and Chi-square based tests – p-value - nonparametric tests – sign test, signed rank test and run test. Analysis of variance – one-way and two-way ANOVA – multiple comparison tests - statistical quality control – control charts for variables and control charts for attributes.

TEXT BOOKS / REFERENCES:

1. Douglas C. Montgomery and George C.Runger, "*Applied Statistics and Probability for Engineers*", Third Edition, John Wiley, 2008.
2. J Ravichandran, "Probability and Statistics for Engineers", First edition, Wiley, 2012.

3. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, "*Probability and Statistics for Engineers and Scientists*", Eighth Edition, Pearson Education, 2007.

MA803 FOURIER TRANSFORM AND WAVELET TRANSFORM 3-1-0-4

Fourier Transforms: Fourier Integral Representations - Proof of The Fourier Integral Theorem - Fourier Transform Pairs - Properties of The Fourier Transform - Transforms of More Complicated Functions - The Convolution Integrals of Fourier - Transforms Involving Generalized Functions - Hilbert Transforms - Introduction- Discrete Fourier Transformation.

Continuous Wavelet Transform : Introduction-Continuous-Time Wavelets- Definition of the CWT-The CWT as Correlation-Constant Q-Factor Filtering Interpretation and Time –Frequency Resolution -The CWT as an Operator-Inverse CWT-Problems
Discrete Wavelet Transforms: Introduction-Approximations of Vectors in Nested Linear Vector Subspaces –Example of Approximating Vectors in Nested Subspaces of a Finite- Dimensional Linear Vector Space-Example of Approximating Vectors in Nested Subspaces of a Infinite-Dimensional Linear Vector Space –Example of an MRA-Bases for the Approximation Subspaces and Harr Scaling Function –Bases for the Approximation Subspaces and Harr Scaling Function-Bases for the Detail Subspaces and Harr Wavelet

TEXT BOOKS / REFERENCES:

1. Larry C.Andrews and Bhimsen K.Shivamoggi, "*Integral Transforms for Engineers*", Prentice Hall, 1999.
2. Raghuveer M.Rao and Ajit S. Bopardikar, "*Wavelet Transforms Introduction to Theory and Application"*, Pearson Education, 1998.
3. Ian N. Sneddon, *"The use of Integral Transforms",* Tata McGraw Hill, 1974.

MA804 GRAPH THEORY 3-0-1-4

Introduction: Definition of graph, degree of vertex, walk, path. Connected graph, complete graphs, Regular graphs and their properties. Euler graph, necessary and sufficient conditions for Euler graph, Hamiltonian graph and its properties. Graph Coloring, Bipartite and planar graphs with properties. Topological operations in graph. Digraph – degree in digraphs-cycles-pan cycles. Connectivity, vertex, edge connectivity matching, maximal matching-perfect matching-k-factor graphs. Adjacency, Incidence and circuit matrices for graphs and digraphs- adjacency list.
Tree: Tree, properties of Trees, distances and centers in a tree, spanning tree, Fundamental Circuits, minimal, maximal spanning tree-rooted binary trees. Vertex and Horizontal constrained graphs, interval, permutations and intersection graphs with simple properties.
Computational Complexity: Introduction to NP completeness, the classes of P and NP, Tractable and Intractable algorithms, Cooks theorem.
Algorithms and Applications: Shortest and longest path algorithm, minimal and maximal spanning tree algorithms, Traveling Salesman algorithms, Planarity test algorithms, maximal matching algorithms, maximal clique algorithm, Coloring algorithms. Applications: VLSI Physical Designs problems, VLSI Circuit Designs, Electrical Networks Communication and Computer Networks.

TEXT BOOKS / REFERENCES:

1. Douglas B.West, *"Graph Theory"*, Second Edition, Pearson Education, 2001.
2. Alan Gibbons, *"Algorithmic Graph Theory"*, Cambridge University Press, 1985.
3. Frank Harary, *"Graph Theory"*, Narosa Publishing House, 2001.

4. Narsing Deo, *"Graph Theory with Applications and Engineering and Computer Science"*, Prentice Hall of India, 2001.

MA805 STATISTICAL INFERENCE AND DESIGN OF EXPERIMENTS 3-1-0-4

Point and Interval Estimation: General concepts - unbiased estimators - Variance and mean square error of an estimator - Methods of point estimation - Confidence interval development for population parameter – mean, variance, proportion – small and large sample cases – Bayes interval estimation.
Tests of Hypotheses: Hypothesis testing – general procedure for hypothesis testing – power of a test –alpha and P-values, choice of sample size, application of various test statistics with the respective distributional properties.
Analysis of Variance and Design of Experiments: Design and analysis of single-factor experiments – model development of completely randomized experiments – multiple comparisons – Randomized block designs – Tests and assumptions based on fixed and random effects models – Design of experiments with several factors – Factorial experiments – General factorial experiments – 2^k factorial experiments – Blocking and confounding – Response surface methodology – Orthogonal experiments.

TEXT BOOKS/ REFERENCES:

1. Douglas C. Montgomery and George C. Runger, *"Applied Statistics and Probability for Engineers"*, Third Edition, John Wiley, 2008.
2. J Ravichandran, "Probability and Statistics for Engineers", First edition, Wiley, 2012.
3. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying Ye, *"Probability and Statistics for Engineers and Scientists"*, Pearson Education Asia, 2004.

MA806 REGRESSION ANALYSIS 3-1-0-4

Simple Linear Regression and Correlation: Empirical Models – Simple Linear Regression – Properties of the Least Squares Estimators Hypothesis Tests in Simple Linear Regression-Uses of *t*-test – Analysis of variance Approach to Test Significance of Regression – Confidence Intervals – Confidence Intervals on the Slope and Intercept – Confidence Interval on the Mean Response – Prediction of New Observations – Adequacy of the Regression Model – residual Analysis – Coefficient of Determination (R^2) – Transformation to a Straight Line – Correlation.
Multiple Linear Regression: Multiple Linear Regression Model-Introduction-Least Square Estimation of the Parameters – Matrix Approach to Multiple Linear Regression – Properties of the Least Squares Estimators – Hypothesis Tests in Multiple Linear Regression – Test for Significance of Regression – tests on Individual Regression Coefficient and Subsets of Coefficients – Confidence Intervals in Multiple Linear Regression – Confidence Interval on Individual Regression Coefficients – Confidence Interval On the Mean response – Prediction of New Observations – Model Adequacy Checking-Residual Analysis – Influential Observations – Aspects of Multiple Regression Modeling – Polynomial Regression Models Categorical Regressors And Indicator Variables – Selection of Variables and Model Building-Multicollinearity

TEXT BOOKS / REFERENCES:

1. Douglas C. Montgomery and George C. Runger, *"Applied Statistics and Probability for Engineers"*, Third Edition, John-Wiley, 2003.
2. J Ravichandran, "Probability and Statistics for Engineers", First edition, Wiley, 2012.
3. Douglas C. Montgomery and Elizabeth A.Peck and G.Geoffrey Vining, *"Introduction to Linear Regression Analysis"*, Third Edition, John Wiley, 2007.

MA807 TIME SERIES ANALYSIS 3-1-0-4

Auto Correlation Functions: Introduction-Times series and stochastic process- Stationary stochastic process-Positive definiteness and the auto covariance matrix , auto covariance and auto correlation functions –estimation of auto covariance and autocorrelation functions-standard error of auto correlation estimates.
Spectrum of stationary Process: Periodogram of a time series- analysis of variance-Spectrum and Spectral density functions-advantages and disadvantages of the auto correlation and spectral density function.
Linear Stationary Models: Expectations, Stationarity and Ergodicity- white noise- Moving average processes- Auto regressive processes-Mixed Auto regressive Moving average processes-The auto covariance –Generating function-Invertibility.
Non-Linear Stationary Models: Introduction-Three explicit forms for the ARIMA Model-Integrated Moving Average process.
Forecasting: Principles of forecasting-Forecast based on an infinite number of observations – Forecast based on a finite number of observations –the triangular factorization of a positive definite symmetric matrix-updating a linear projection-optimal forecasts for Guassian processes-sums of ARMA processes-Wold's decomposition and the Box Jenkins modeling

TEXT BOOKS /REFERENCES:

1. George E.P.Box , Gwilym.M.Jenkins, and Gregory C. Reinsel, *"Time Series Analysis-Forecasting and Control"*, Fourth Edition, John Wiley, 2008.
2. James D. Hamilton, *"Time Series Analysis"*, Princeton University Press, 2008.

MA808 WAVELET METHODS FOR TIME SERIES ANALYSIS 3-1-0-4

The discrete wavelet transform for time series: Introduction-the wavelet filter – the scaling filter – first stage of the pyramid algorithm – second stage of pyramid algorithm – general stage of pyramid algorithm – examples.
The maximal overlap discrete wavelet transform: Introduction – MODWT wavelet and scaling filters – basic concepts for MODWT – Pyramid algorithm for the MODWT - examples.
The wavelet variance: Introduction – definition and rationale for the wavelet variance – basic properties of the wavelet variance – estimation of the wavelet variance – confidence intervals for the wavelet variance – spectral estimation via the wavelet variance – examples.
Analysis and syntheses of long memory processes: Introduction-discrete wavelet transform of a long memory process – simulation of a long memory process – maximum likelihood estimator and least square estimation for FD processes – testing homogeneity of variance – examples.

TEXT BOOKS /REFERENCE

1. Donald B. Percival and Andrew T. Walden, *"Wavelet Methods for Time Series Analysis"*, Cambridge University Press, 2006.
2. George E.P. Box, Gwilym M. Jenkins and Gregory C. Reinsel, *"Time series analysis-Forecasting and Control"*, Fourth Edition, John Wiley, 2008.
3. James D. Hamilton, *"Time Series Analysis"*, Princeton University Press, 2008.

MA809 ADVANCED ALGEBRA 4-0-0-4

Structure of Finite Fields: Characterization of Finite Fields, Roots of Irreducible polynomials Traces, Norms and Bases, Roots of Unity and Cyclotomic Polynomials, Representation of Elements of Finite Fields.
Polynomial over Finite Fields: Order of Polynomials and Primitive Polynomials, Irreducible Polynomials, Construction of Irreducible Polynomials, Linearized Polynomials, Binomials and Trinomials. Factorization over small Finite Fields, Factorization over large Finite Fields, Calculation of roots of Polynomials.
Permutation Polynomials: Criteria for Permutation Polynomials, Special Type of Permutation Polynomials, Groups of Permutation Polynomials, Exceptional Polynomials, Permutation Polynomials in several indeterminate.

TEXT BOOKS / REFERENCES:

1. Rudolf Lidl and Harald Niederreiter, "*Finite Fields*", Second Edition, Cambridge University Press, 1997.
2. Joseph Rotman, "*Galois Theory*", Second Edition, Springer, 1998.
3. I.N. Herstein, "*Topics in Algebra*", Second Edition, John Wiley, 1975.

MA810 COMPUTER AIDED DESIGN OF VLSI CIRCUITS 3-1-0- 4

Introduction of Design Methodologies and Graph Theory: The VLSI Design Problems- Design Methods –Design Cycle – Physical Design Cycle-Design Styles. Algorithmic and System Design-Structural and Logic Design-Layout Design. Graph terminologies – Data structures for the representation of Graphs – Algorithms: DFS-BFS-Dijkstra's shortest path algorithm – Prim's algorithm for minimum spanning trees. Combinatorial Optimization Problems – Complexity Class-P-NP Completeness and NP Hardness problems.
Placement, Partitioning and Floor Planning: Types of Placement Problems – Placement Algorithms – K-L Partitioning Algorithm. Optimization Problems in Floor planning - Shape Function and Floor plan Sizing
Routing and Compaction: Types of Routing Problems – Area Routing – Channel Routing – Global Routings. 1D and 2D Compaction. Gete level – Switch level Modeling and Simulations.

TEXT BOOK / REFERENCES:

1. Gerez, *"Algorithms for VLSI Design Automation",* John Wiley & Sons, 2000.
2. Naveed Sherwani, *"Algorithms for VLSI Physical Design Automation"*, Second Edition, Kluwer Academic Publishers, 1995.
3. Sadiq M Sait and Habib Youssef, *"VLSI Physical Design Automation: Theory and Practice"*, IEET, 1999.
4. M. Sarrafzadeh and C. K. Wong, *An Introduction to VLSI Physical Design*, McGraw-Hill, New York, 1996.
4. Giovanni De Micheli, *Synthesis and Optimization of Digital Circuits*, Tata McGraw Hill, 1994.

MA811 VLSI ROUTING ALGORITHMS 4-0-0-4

Introduction and Graph Theory Algorithms: System Physical Design Cycle –VLSI Chip Routing Techniques-Routing Approaches- Minimum Layout. Graph terminologies – Data structures for the representation of Graphs – General Algorithmic Approaches -Optimization Problems – Complexity Class-P-NP Completeness and NP Hardness problems.
Channel Routing and OTC Routing: Classification of Channel Routing Algorithms – River Routing Algorithms- Multi-Layer Routing Algorithms. OTC Routing problems for BTM, CTM, MTM, and TBC.

Routing Algorithms for Multi-Layer Process: Classification of BTM Routing Algorithms- MIS, ILP Algorithms. Routing Algorithms for CTM and MTM.
Thin-Film MCMs: Minimum Width Cell Layouts – Multirow Net Connection Assignment – Net Classification – Interval Selection Topological Routing Approach.

TEXT BOOKS /REFERENCES:

1. Naveed A. Sherwani, *"Routing in the Third Dimension"*, IEEE Press, 1995.
2. Prashant Saxena, Rupesh S. Shelar, Sachin Sapatnekar, " Routing Congestion in VLSI Circuits: Estimation and Optimization", Springer, 2007.
3. Andrew B Kahng and Gabriel Robins, *"On Optimal Interconnections for VLSI"*, Computers, 1994.
4. Sadiq M Sait and Habib Youssef, *"VLSI Physical Design Automation: Theory and Practice"*, IEET, 1999.
5. Sung Kyu Lim, Practical Problems in VLSI Physical Design Automation, Springer, 2008.

MA812 FUNCTIONAL ANALYSIS 3-1-0-4

Metric Spaces, Vector Spaces: Metric Spaces, Examples of Metric Space, Vector Spaces, Examples of Vector Spaces, Subspaces, Linear Independence, Basis and dimension, Cauchy sequence, Convergent sequence, Complete Metric Space.
Normed Linear Spaces, Banach Spaces: Normed spaces, Properties of Normed Spaces, Banach Spaces, Compact Space, Linear operators, Linear functional, Normed Spaces of operators, Dual Spaces.
Inner Product Spaces. Hilbert Spaces: Inner Product Space, Hilbert Space, Properties of Inner Product Spaces, Orthogonal complement and direct sums, Orthonormal sets and sequences, Hilbert adjoint operator, Self-adjoint, Unitary and Normal Operators.
Applications: Banach fixed point theorem, Application of Banach's theorem to linear equations, Differential Equations and Integral Equations-Approximation in Normed Linear Spaces, Strict convexity, Uniform approximation. Chebychev's polynomials, Approximation in Hilbert space and splines.

TEXT BOOKS / REFERENCES:

1. Balmohan Limaye, *"Functional Analysis"*, New Age International, 1996.
2. Erwin Kreyszig, "*Introductory Functional Analysis with Applications"*, John Wiley, 2006.

MA813 TENSOR ANALYSIS AND FINITE ELEMENT METHODS 3-1-0-4

Introduction to Vector and Tensor analysis: Vectors – Vector Spaces - Tensors - Differential forms – Variational principles – n^{th} rank tensor in m dimensional space – Cartesian Tensors - Theory and applications to geometry and Mechanics – Tensor analysis on manifolds.
Introduction to FEM : General procedure for finite element analysis - Types of finite elements in one, two and three dimensions - Shape functions, Interpolation functions for general finite element formulation - Convergence criteria, compatibility requirements, geometric isotropy invariance.
Formulation of finite element equations: Direct approach - Variational approach - Basics of calculus of variation, Euler-Lagrange equations, principles of minimum potential energy, Rayleigh-Ritz method, Weighted residuals approach – Point collocation method, subdomain collocation method, method of least squares, Galerkin method Derivation and assembly of stiffness matrices for various applications, implementation of boundary conditions.
Solution Techniques: Numerical integration – Gaussian quadrature – Wilson θ method

Direct methods – Gauss elimination method, Choleski decomposition, frontal method
Iterative techniques – gradient based methods and preconditioners - Eigen Values

TEXT BOOKS /REFERENCES:

1. Murray Speigal, *"Vector Analysis"*, Sura Books, 1994.
2. James G Simmonds, *"A brief on Tensor analysis",* Springer, 1994.
3. David Hutton, *"Fundamentals of Finite Element Analysis"*, Tata McGraw-Hill, 2005.
4. Singiresu S. Rao, *"The Finite Element Method in Engineering"*, Third Edition, Butterworth-Heinemann, 2001.

MA814 NETWORK ON CHIP 2-0-1-3

Graph terminologies – Types of Graphs- Graph Algorithms: Shortest Path-Maximal Flow-Minimal Spanning Tree-Graph Partitioning.
Introduction to NoC-SoC objectives and NoC needs-Network Architecture for on chip relations-Ad HOC Network Architectures-Component Design for NoCs-Properties of Network Architecture.
Physical Network Layer: Interconnection in DSM SoC-High performance Signaling-Buliding Blocks.
Network and Transport Layers in NoC: NoC QoS-NoC Topology-Switching Techniques-NoC Routing-NoC Addressing-Congestion and Flow control.
NDesign Methodologies and CAD Tol Flows for NoCs: Network Analysis and Simulation-Network Systhesis and Optimization-Design flow for NoC.

TEXT BOOKS / REFERENCES

1. Glovanni De Micheli and Luca Benini, *"Network on Chip: Technology and Tools"*, Morgen Kaufmann Publisher, 2006.
2. Srinivasan Murali Designing Reliable and Efficient Networks on Chips, Springer, 2009.
3. Axel Jantsch and Hannu Tenhunen, *"Network on Chip"*, Kulwer Academy, 2010.
4. Nicopoulos**,** Chrysostomos and Narayanan**,** *"Network-on-Chip Architectures: A Holistic Design Exploration"*, Lecture Notes in Electrical Engineering, Springer, 2009.

MA815 MATHEMATICAL FOUNDATIONS OF INCOMPRESSIBLE FLUID FLOW 4-0-0-4

Kinematics of Fluids in motion – Lagrangian and Eulerian methods – Equation of continuity – Boundary conditions – Kinematic and physical – steam line, path line and streak line – velocity potential – vorticity- rotational and irrotational motion.
Equation of Motion of Compressible Viscous Fluid (Navier-Stokes Equations)-General Properties –Equation of motion of inviscid fluid – Euler's equation – impulsive force –physical meaning of velocity potential-energy equation – Lagrange's hydrodynamical equations — Bernoulli's equation and its applications-Motion in two-dimensions and sources and sinks – irrotational motion – complex potential-Milne-Thomson circle theorem –Blasius theorem. General theory of irrotational motion – flow and circulation – Stoke's theorem – Kelvin's Circulation theorem – Permanence of irrotational motion - Kelvin's minimum energy theorem Viscous Incompressible flow - Dimensional Analysis – Buckingam π theorem. Exact Solutions of Navier Stokes Equations – Small Reynold's number flows – flow past a sphere –Stokes flow – Whitehead's paradox- Flow past a circular cylinder – Stoke's Paradox.

TEXT BOOKS / REFERENCES:

1. G.K.Batchelor, "*An Introduction to Fluid Dynamics*", Cambridge University Press, 1997.
2. L.M. Milne-Thompson, "*Theoretical Hydrodynamics*", Dover Publications, 1968.
3. Victor L. Streeter and E.Benjamin Wylie, "*Fluid Mechanics*", Mc Graw Hill, 1983.
4. S.W. Yuan, "*Foundations of Fluid Mechanics*", Prentice Hall, New Jersey, 1970.

MA816 MATHEMATICAL THEORY OF MAGNETOHYDRODYNAMICS 4-0-0-4

Electromagnetic field equations – Maxwell's equations - Electromagnetic effects and the magnetic Reynolds number – induction equation. Alfven's Theorem – Ferraro's Law of irrotation – Electromagnetic stresses. Magnetohydrostatics and steady states – Hydromagnetic equilibria and Force free magnetic fields —Chandrasekhar's theorem – General solution of force free magnetic field when α is constant – Some examples of force free fields. Steady laminar motion – Hartmann flow. Tensor electrical conductivity, Hall current and ion slip – simple flow problems with tensor electrical conductivity. Magnetohydrodynamic waves - Alfven waves –Stability of hydromagnetic systems - Normal mode analysis - Squire's theorem – Orr-Sommerfield equation- Instability of linear pinch – Flute instability – A general criterion for stability – Bernstein's method of small oscillations – Jeans Criterion for Gravitational stability – Chandrasekhar's generalization for MHD and rotating fluids.

TEXT BOOKS / REFERENCES:

1. Ferraro, V.C.A and Plumpton, C., "*An Introduction to Magneto-Fluid Mechanics*", Clarendon Press, Oxford, 1966.
2. M.R.Crammer, and Shi-I Pai, *"Magneto-Fluid Dynamics for Engineers and Applied Physicists"*, Scripta Publishing Company, Washington, 1973.
3. P.H. Roberts, *"An Introduction to Magnetohydrodynamics"*, Longmans, Green and Co, London, 1967.
4. S.Chandrasekhar, "*Hydrodynamic and Hydromagnetic Stability*", Dover Publications, 1981.

MA 817 GEOPHYSICAL FLUID DYNAMICS 3-0-0-3

Introduction – Equations of Motion in rotating frame of reference – potential vorticity – non-dimensional parameters and their significance. Geostrophic Flow – Taylor-Proudman Thorem – Taylor Coloumn – Application to Geophysical Motion - β -plane Approximation. Ekman Layer – Ekman Layer Equations – Cylindrical Flow – Ekman Layer Spiral – Mass Transport in Ekman Layer – Spin-up time scale – Tea-cup experiment. Geostrophic modes – in a sphere – Geostrophically free, guided and blocked regions – Circulation. Inertial Modes - λ real and $|\lambda| > 2$ - Orthogonality – Mean Circulation Theorem – Initial Value Problem – Inertial Modes in a Cylinder – Plane Wave Solution. Rossby Waves – Sliced Cylinder - β-plane problem – plane wave solution. Vertical Shear layers - $E^{1/3}$ and $E^{1/4}$ Layers – Sliced Cylinder – An Ocean Model – Sverdrup's Relation. Analogies between rotation and stratification - Normal mode problem for rotating stratified flow – steady flow – potential vorticity – Rossby Waves in a rotating stratified fluid – Rossby radius of deformation.

TEXT BOOKS /REFERENCES:

1. Susan Friedlander, "*An Introduction to Mathematical Theory of Geophysical Fluid Dynamics*", North-Holland Publishing Company, 1980.
2. Joseph Pedlosky, "*Geophysical Fluid Dynamics*", Springer- Verlag, New York, 1987.

3. Harvey P. Greenspan, "*The Theory of Rotating Fluids*", Cammbridge Monographs on Mechanics and Applied Mathematics, Cambridge University Press, 1980.

MA818 ADVANCED BOUNDARY LAYER THEORY 4-0-0-4

Introduction – limitations of ideal fluid dynamics – Importance of Prandtl's boundary layer theory - boundary layer equations in two dimensional flows – boundary layer flow over a flat plate – Blasius solution – Boundary layer over a wedge – energy integral equation for two-dimensional laminar boundary layers in incompressible flow – application of Von Karman's integral equations to boundary layer with pressure gradient
Displacement, momentum, energy thickness – axially symmetric flows – momentum equation for laminar boundary layer by von Karman – Wall shear and drag force on a flat plate due to boundary layer – coefficient of drag. Boundary layer equations for a 2D viscous incompressible fluid over a plane wall – Similar solutions – Separation of boundary layer flow. Hydromagnetic Boundary layers – Hartman Layer – MHD Blasius flow. Thermal boundary layers – thermal boundary layer equation in two dimensional flow – Thermal boundary layers with and without coupling of velocity and temperature field – forced convection in a laminar boundary on a flat plate – Polhausen's method of exact solution for the velocity and thermal boundary layers in free convection from a heated plate – thermal energy integral equation. Boundary layer control using suction and injection.

TEXT BOOKS /REFERENCES:

1. H.Schlichting and K.Gersten, *"Boundary Layer Theory",* Eighth Edition, Springer, 2000.
2. L. Rosenhead*, "Laminar Boundary Layers",* Dover, 1988.
3. G.K.Batchelor, "*An Introduction to Fluid Dynamics"*, Cambridge University Press, 1993.
4. P.H.Roberts *, "An Introduction to MHD"* , Longmans, 1967.

MA819 GENERALIZED MATRIX FUNCTIONS 4-0-0-4

Matrix function: Introduction to matrix functions, generalized matrix functions, Schur functions, immanent functions. Binet-Cauchy theorem.

Permanent: Introduction, Properties of permanent Polya's problem, Schurs inequality, and van-der Waerden's Conjecture. Evaluation of permanents by Binet-Minc and Ryser's algorithms.

Matrices: Matrices of 0's and 1's, lower and upper bounds for permanent of (0, 1) matrices, Non-negative, positive definite, doubly stochastic matrices, and Hermitian matrices.

Multilinear Algebra: Generalized Cramer's rule, Generalized inverse, diversity of generalized inverses, Jordan and Smith normal forms. Moore-Penrose inverse, {1}, {1,2}, {1,2,3} inverses, and Bott-Duffin Inverse.

TEXT BOOKS /REFERENCES:

1. H. Minc, Permanents, *"Encyclopedia of Mathematics and its Applications"*, Vol. 6, *Addison – Wesley, Reading, Mass*, 1978.

2. R. A. Brualdi and H. Ryser, *"Combinatorial Matrix Theory", Cambridge University press,* 1991.

3. Adi Ben-Israel and Thomas N.E Greville, "Generalized Inverse Theory and Applications", CMS, 2002.

MA820 VECTOR BUNDLES 3-0-0-3

Vector bundles–Definition, Sections on Vector Bundles. Operations on Vector Bundles–Direct Sum, Tensor Product, Dual Bundle and Exterior Power. Subbundles and Quotient Bundles–Homomorphism of Vector Bundles , Kernel, Image and Cokernal, Metric on a Bundle, Complementary Bundle. Vector Bundles over Compact Spaces–Equivalence between the Category of Vector Bundles and the Category of Finitely Generated Projective Modules, Homotopic Classification of Vector Bundles. Additional Structures–Orthogonal, Symplectic and Quarternion Bundles. G-bundles over G-Spaces–Homotopic Classification of G-bundles. Principal Bundles, Structure Groups and Transition Functions.

TEXT BOOKS / REFERENCES:

1. M.Atiyah, *"K-Theory"*, Levant Books, 2009
2. Husemoller, Dale ,*"Fibre Bundles"*, Third Edition , Springer Verlag, 1994.
3. N.Steenrod, *"The Topology of Fibre Bundles"*, Princeton University Press, 1974.

MA 821 THEORY OF MANIFOLDS 3-0-0-3

Definition of Manifolds, Differentiable and Analytic Manifolds, Examples of Manifolds, Product of Manifolds, Mappings between Manifolds, Submanifolds, Tangent Vectors, Differentials, The Differential of a Function, Infinitesimal Transformation, Tangent Space, Tangent Vector, Cotangent Space, Vector Fields, Smooth Curve in a Manifold. Differential Forms– k-forms, Exterior Differential, its Existence and Uniqueness, Exact Differential Forms. De Rham Cohomology Group, Betti Number, Poincare's Lemma, Inverse Function Theorem, Implicit Function Theorem and its Applications, Integral Curve of a Smooth Vector Field. Orientable Manifolds–Definition and Examples. Smooth Partition of Unity– Definition and Existence. Riemannian Manifolds– Definition and Examples.

TEXT BOOKS / REFERENCES:

1. P.M. Cohn, *"Lie Groups"*, Cambridge University Press, 1965.
2. Claude Chevalley, *"Theory of Lie Groups"*, Fifteenth Reprint, Princeton University Press, 1999.

MA 822 LIE ALGEBRAS 4-0-0-4

Basic Concepts–Definition and Examples, Lie Algebra of Derivations, Adjoint Representation, Structure Constants, Direct Sums, Homomorphism and Isomorphisms, Ideals, Centre and Derived Algebra of a Lie Algebra, Simple Lie Algebras, The Normalizer of a Subalgebra and Centralizer of a Subset in Lie Algebras, Automorphism and Inner Automorphism of a Lie Algebra, Descending Central Series of a Lie Algebra, Nilpotent Lie Algebras. Derived Series of a Lie Algebra, Radical of a Lie Algebra, Solvable Lie Algebras, Engel's Theorem. Semisimple Lie Algebras–Theorems of Lie and Cartan, Jordan- Chevalley Decomposition, Cartan's Criterion. Killing Form, Inner Derivations, Abstarct Jordan Decomposition, Complete Reducibility of Lie algebras, Cartan Subalgebras, The Weyl Group, Root Systems.

TEXT BOOKS / REFERENCES:

1. Jacobson, "*Lie Algebras*", Dover, 1979.

2. J.P. Serre, "*Lie Algebras and Lie Groups*" , Benjamin, 1965 (Translated from French).
3. J.E. Humphreys, "*Introduction to Lie Algebras and Representation Theory"*, Springer-Verlag, 1980.

MA 823 LIE GROUPS 4-0-0-4

Analytic Groups− Definition and Examples, Lie algebra of an Analytic Group− Definition and Examples, Analytic Subgroups, Closed Analytic Subgroups, Analytic Homomorphisms, Factor Groups of an Analytic Group, The Exponential Mapping, Canonical Coordinates, Lie Groups, Matrix Lie Groups, The Matrix Exponential, Matrix Logarithm, Further Properties of the Matrix Exponential, The Lie Algebra of Matrix Lie Groups, The General Baker-Campbell-Hausdorff Formula, The Derivative of the Exponential Mapping, Quotient Groups and Covering Groups, Differential Forms and Haar Measure, Examples of Non Matrix Lie Groups.

TEXT BOOKS / REFERENCES:

1. Brian C.Hall, "*Lie Groups, Lie Algebras and Representations*", Springer-Verlag, 2004.
2. P.M.Cohn, "*Lie Groups*", Cambridge University Press, 1965.
3. Claude Chevalley, "*Theory of Lie Groups*", Fifteenth Reprint, Princeton University Press, 1999.
4. Peter J. Oliver, "*Applications of Lie Groups to Differential Equations",* Second Edition, Springer, 2000.

MA 824 REPRESENTATION THEORY OF LIE ALGEBRAS 4-0-0-4

Modules and Representation and their Equivalence, Homomorphism of Modules, Irreducible Modules, Direct sums of Representations, Tensor products of Representations, Dual Representations, Schur's Lemma, Complete Reducibility, Casimir Element of a Representation, Weyl's Theorem on Complete Reducibility, Preservation of Jordan Decomposition, Cassification of Irreducible Modules over the Special Linear Algebra of Dimension Two, Representation of Complex Semisimple Lie Algebras−Integral and Dominant Integral Elements, The Theorem of Highest Weight, Verma Modules, Peter-Weyl theorem, The Weyl Character Formula.

TEXT BOOKS / REFERENCES:

1. Jacobson, "*Lie Algebras*", Dover, 1979.
2. J.-P. Serre, "*Lie Algebras and Lie Groups*", Benjamin, 1965. (Translated from French).
3. J.E. Humphreys, "*Introduction to Lie Algebras and Representation Theory*", Springer-Verlag, 1980.
4. Brian C.Hall, "*Lie Groups, Lie Algebras and Representations*", Springer-Verlag, 2004.

MA825 SPECTRAL GRAPH THEORY AND ITS APPLICATIONS 3-0-0-3

Adjacency matrix and Laplacian, Intuition, spectral graph drawing, Physical intuition
Isomorphism testing.
Random walks. Graph Partitioning and clustering, Distributions of eigenvalues and compression, Computation.
Energy minimization.

Randomized algorithms and Markov chains. Construction of expander graphs.

TEXT BOOKS / REFERENCES:

1. Fan R. K. Chung. *Spectral Graph Theory*. CBMS Regional Conference Series in Mathematics, 1997.
2. S. Horry, N. Linial, and A. Wigderson. Expander Graphs and Their Applications. Bulletin of the American Mathematical Society, 43(4):439-561, 2006.
3. C. Godsil and G. Royle. Algebraic Graph Theory. Graduate Texts in Mathematics 207, Springer
4. D. A. Levin, Y. Peres and E. L. Wilmer. Markov Chains and Mixing Times. American Mathematical Society, 2008.

MA 826 PROBABILITY THEORY 4-0-0-4

Probability-structure and properties of probability spaces, Conditioning and Independence, Discrete Sample Spaces, The Sample Space R, The Sample Space R^d, The Sample Space of Closed Sets of R^d, Random variables, Distributions of Random variables, The concept of expectation of random variables, Properties of expectation, Computations of expectation, Independence and Conditional Distributions. Distribution Theory- The Method of Transformations, the Method of Convolution, Generating Functions, Characteristic Functions. Convergence Concepts: - Convergence of Random variables, Convergence of Moments, Convergence in Distribution, Convergence of Probability Measures. Limit Theorems for Large Sample Statistics-Laws of Large Numbers -independent random variables and Independent and identically distributed random variables, Central Limit Theorem-Independent and identically distributed random variables, Independent random variables, large deviations. Conditional Expectation and Martingales, Properties of Conditional Expectation and Martingales.

TEXT BOOKS/ REFERENCES:

1. Hung T. Nguyen and Tonghui Wang, "*A Graduate Course in Probability and Statistics, Volume I: Essentials of Probability for Statistics*", Tsinghua University Press, 2007.
2. V. K. Rohatgi, "*An Introduction to Probability Theory and Mathematical Statistics*", Wiley Eastern Limited, 1976.
3. P. Billingsley, "*Probability and Measure*", Second Edition, John Wiley & Sons (SEA), 1995.
4. J.S. Rosenthal, "*A First Look at Rigourous Probability Theory*", World Scientific, 2000.

MA827 CENTRALITY AND CONVEXITY IN GRAPHS 3-0-0-3

Distances – geodetic and detour distances. Centers-center and eccentricity, self -centered graphs, Median, central paths. Generalized centers.
Convexities- geodetic convexity, convex hulls. Closure invariant – geodetic iteration numbers, convexity numbers, geodetic numbers and hull numbers. Geodetic and hull numbers and related metric sets on product graphs – Cartesian and strong product of graphs, Order and Metric Convexities in z raised to the power n.
Transit functions on graphs – geodetic transit function, induced path transit function, all path transit function, cut-vertex transit function, detour transit function. The Single paths transit functions and longest path transit functions, Transit functions on POsets.

TEXT BOOKS/ REFERENCES:

1. F. Buckley and F. Harary, “*Distance in Graphs*”, Addison-Wesley, Redwood city, CA,1990. (chapters 2 and 7)
2. M. G. Everett and S. B. Seidman, “*The hull number of a graph*”, Discrete Math., 57, (1985), 217-223.
3. G. Chartrand, C.E. Wall, and P. Zhang, “*The convexity number of a graph*”, Graphs Comb. 18 (2002), 209-217.
4. G. Chartrand, F. Harary and P. Zhang, “*On the geodetic number of a graph*”, Networks, **39** (2002), 1-6.
5. Brešar, B, Klavžar, S and Horvat, A.T, “*On the geodetic number and related metric sets in Cartesian product graphs*”, Discrete. Math. **308**(2008), 5555–5561.
6. “*Convexity in Discrete Structure*”, RMS Lecture Notes Series, No. 5(2008).
7. Henry Martyn Mulder, "*Transit Functions on Graphs (and Posets)*", Econometric Institute Report EI 2007-13.

MA 828 ADVANCED NUMERICAL ANALYSIS 3-0-0-3

Numerical solution of linear and non-linear equations: Jacobi, Gauss-Seidel and Relaxation methods. Diagonal – dominance as necessary condition for convergence, Newton-Raphson and secant methods for non-linear equations. Numerical solution of Ordinary Differential Equations: Runge-Kutta and Multi-step methods including variable – step size Runge-Kutta-Fehlberg methods, Adam’s and Milne’s methods. Numerical integration: Quadrature formulae, Singular integrals, Multidimensional numerical integration, applications. Finite difference, shooting and finite element methods of solving boundary value problems, Calculus of variations, Galerkin and Rayleigh – Ritz methods, Kantorovich-Galerkin methods for simple partial differential equations. Numerical solution of partial differential equations: Finite difference and finite element methods,

Note:
1. Matlab/SciLab/Maple/Mathematica/python programs to be used for implementing numerical methods.
2. Stability and Convergence Analysis to be made for relevant methods above.

TEXT BOOKS/REFERENCES:

1. Steven C. Chapra and Raymond P. Canale, “Numerical Methods for Engineers”, Fifth Edition, Tata McGraw-Hill Publications, New Delhi, 2006
2. Curtis F. Gerald and Patrick O. Wheatley, “Applied Numerical Analysis”, Sixth Edition, Pearson Education, 2003.
3. Daniel R. Lynch, “Numerical Partial Differential Equations for Environmental Scientists and Engineers: A First Practical Course”, Springer, 2005.
4. Alfio Quarteroni, Riccardo Sacco and Fausto Saleri, “Numerical Mathematics”, Second Edition, Springer, 2007.

MA 829 STATISTICAL METHODS IN BIOINFORMATICS 4-0-0-4

Introduction to bioinformatics, Markov chains and HMM, parameter estimation for HMM, Complex Markov Chains, numerical stability of HMM, pair wise alignment using HMM, profile HMMS for sequence families, adding insert and delete states to obtain profile HMMS, searching with profile HMM.

Probabilistic approaches to phylogenetic tree, Maximum Parsimony analysis, Fitch-Margoliash algorithm for the three sequences, Jukes-Cantor model of sequence evolution, Minimum evolution (ME) methods, Evolutionary models based on gene expressions and micro-array data, Bootstrapping, calculating likelihood for ungapped alignments, Maximum Likelihood.

Machine learning foundation: Probabilistic frame work, Probabilistic modeling and inference, EM/GEM algorithms, Markov chain Monte Carlo, simulated annealing, Evolutionary and genetic algorithms, Neural Network applications in bioinformatics, Probabilistic graphical models in bioinformatics, Introduction to Support vector machine, and other Kernel methods, classification and dimensionality reduction of gene expression data, Introduction to microarray data, Probabilistic modeling of array data, clustering and gene regulation, stochastic grammars, stochastic context-free grammars based RNA profiles.

TEXT BOOKS/REFERENCES:

1. Richard Durban and Sean.R.Eddy, "*Biological Sequence Analysis, Probabilistic Models of Proteins and Nucleic Acids*", Cambridge University press, 1998.
2. Pierre Baladi and Soren Brunak, "*Bioinformatics: the Machine Learning Approach*", Second Edition, MIT Press, 2001.

MA 830 RAMSEY THEORY 4-0-0-4

Introduction to Combinatorics, Pigeonhole Principle, Dilworth's theorem, Schoreder –Bernstein theorem, Ramsey numbers, Classical Ramsey's theorem, Bipartite Ramsy Theorem, Induced Ramsey theorem, Canonical Ramsey theorem and graph Ramsey theory. Compactness principle, Erdos—Szekeres theorem, Van der Waerden's Theorem and its generalization—The Hales Jewett theorem, Shelah's proof of the Hales Jewett theorem, Schur's theorem and its generalization--Rado's theorem, Erdos-Turan Conjecture and Roth's theorem, Sidon sets, Szemeredi's theorem for Arithmetic Progressions of length 4.

TEXT BOOKS/REFERENCES:

1. Ronald Graham, Bruce Rothschild and Joel Spencer, "Ramsey Theory", Second Edition, John Wiley and Sons, 1990
2. Bruce Landman and Aaron Robertson, "Ramsey Theory on the Integers", *Student Mathematical Library,* vol. 24, 2003
3. Terrence Tao and Van Vu, "Additive Combinatorics", Cambridge University Press, 2006
4. Ronald Graham, "Rudiments of Ramsey Theory", American Mathematical Society, 1981
5. Alexander Soifer, "Ramsey Theory: Yesterday, Today and Tomorrow", Springer, New York, 2011
6. Szemeredi, "On Set of Integers Containing No 4 Elements in AP", Acta Math. Acad. Sci. Hungar. 20, pp. 89-104, 1969