Department of Mathematics
Indian Institute of Technology Guwahati

Guwahati 781 039, India

Course Syllabus (2012 Onwards)

MA501 Discrete Mathematics [3-1-0-8] Prerequistes: Nil

Set Theory - sets and classes, relations and functions, recursive definitions, posets, Zorn - s lemma, cardinal and ordinal numbers; Logic - propositional and predicate calculus, well-formed formulas, tautologies, equivalence, normal forms, theory of inference. Combinatorics - permutation and combinations, partitions, pigeonhole principle, inclusion-exclusion principle, generating functions, recurrence relations. Graph Theory - graphs and digraphs, Eulerian cycle and Hamiltonian cycle, adjacency and incidence matrices, vertex colouring, planarity, trees.

Texts:

1. J.P. Tremblay and R. Manohar, Discrete Mathematical Structures with Applications to Computer Science, Tata McGraw Hill, New Delhi, 2001.
2. C. L. Liu, Elements of Discrete Mathematics, 2nd Edn., Tata McGraw-Hill, 2000.

References:

1. K. H. Rosen, Discrete Mathematics & its Applications, 6th Edn., Tata McGraw-Hill, 2007.
2. V. K. Balakrishnan, Introductory Discrete Mathematics, Dover, 1996.
3. J. L. Hein, Discrete Structures, Logic, and Computability, 3rd Edn., Jones and Bartlett, 2010.
4. N. Deo, Graph Theory, Prentice Hall of India, 1974.

MA511 Computer Programming [3-0-2-8] Prerequistes: Nil

Introduction - the von Neumann architecture, machine language, assembly language, high level programming languages, compiler, interpreter, loader, linker, text editors, operating systems, flowchart; Basic features of programming (Using C) - data types, variables, operators, expressions, statements, control structures, functions; Advance programming features - arrays and pointers, recursion, records (structures), memory management, files, input/output, standard library functions, programming tools, testing and debugging; Fundamental operations on data - insert, delete, search, traverse and modify; Fundamental data structures - arrays, stacks, queues, linked lists; Searching and sorting - linear search, binary search, insertion-sort, bubble-sort, selection-sort; Introduction to object oriented programming.

Programming laboratory will be set in consonance with the material covered in lectures. This will include assignments in a programming language like C and C++ in GNU Linux environment.

Texts:

1. A. Kelly and I. Pohl, A Book on C, 4th Ed., Pearson Education, 1999.

References:

1. H. Schildt, C: The Complete Reference, 4th Ed., Tata Mcgraw Hill, 2000.
2. B. Kernighan and D. Ritchie, The C Programming Language, 2nd Ed., Prentice Hall of India, 1988.
3. B. Gottfried and J. Chhabra, Programming With C, Tata Mcgraw Hill, 2005.

MA521 Modern Algebra [3-1-0-8] Prerequisites: Nil

Groups, subgroups, homomorphism; Group actions, Sylow theorems; Solvable and nilpotent groups; Rings, ideals and quotient rings, maximal, prime and principal ideals; Euclidean and polynomial rings; Modules; Field extensions, Finite fields.

Texts:

1. D. Dummit and R. Foote, Abstract Algebra, Wiley, 2004.
2. N. McCoy and G. Janusz, Introduction to Abstract Algebra, 7th Edn.,Trustworthy Communications, Llc, 2009

References:

1. I. N. Herstein, Topics in Algebra, Wiley, 2008.
2. J. Fraleigh, A First Course in Abstract Algebra, Pearson, 2003.
3. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, Cambridge University Press, 1995.

MA522 Linear Algebra [3-1-0-8] Prerequisites: Nil

Systems of linear equations, vector spaces, bases and dimensions, change of bases and change of coordinates, sums and direct sums; Linear transformations, matrix representations of linear transformations, the rank and nullity theorem; Dual spaces, transposes of linear transformations; trace and determinant, eigenvalues and eigenvectors, invariant subspaces, generalized eigenvectors; Cyclic subspaces and annihilators, the minimal polynomial, the Jordan canonical form; Inner product spaces, orthonormal bases, Gram-Schmidt process; Adjoint operators, normal, unitary, and self-adjoint operators, Schur's theorem, spectral theorem for normal operators.

Texts:

1. S. Axler, Linear Algebra Done Right, 2nd Edn., UTM, Springer, Indian edition, 2010.
2. K. Hoffman and R. Kunze, Linear Algebra, Prentice Hall of India, 1996.

References:

1. G. Schay, Introduction to Linear Algebra, Narosa, 1997.
2. G. Strang, Linear Algebra and Its applications, Nelson Engineering, 4th Edn., 2007.

MA541 Real Analysis [3-1-0-8] Prerequisites: Nil

Convergence of sequence of real numbers, real valued functions of real variables, differentiability, Taylor's theorem; Functions of several variables - limit, continuity, partial and directional derivatives, differentiability, chain rule, Taylor's theorem, inverse function theorem, implicit function theorem, maxima and minima, multiple integral, change of variables, Fubini's theorem; Metrics and norms - metric spaces, convergence in metric spaces, completeness, compactness, contraction mapping, Banach fixed point theorem; Sequences and series of functions, uniform convergence, equicontinuity, Ascoli's theorem, Weierstrass approximation theorem.

Texts:

1. P. M. Fitzpatrick, Advanced Calculus, 2nd Edn., AMS, Indian Edition, 2010.
2. N. L. Carothers, Real Analysis, Cambridge University Press, Indian Edition, 2009.

References:

1. J. E. Marsden and M. J. Hoffman, Elementary Classical Analysis, 2nd Edn., W. H. Freeman, 1993.
2. W. Rudin, Principles of Mathematical Analysis, 3rd Edn., McGraw Hill, 1976.

MA512 Data Structures and Algorithms [3-0-2-8] Prerequistes: MA 511 Computer Programming.

Asymptotic notation; Sorting - merge sort, heap sort, priortiy queue, quick sort, sorting in linear time, order statistics; Data structures - heap, hash tables, binary search tree, balanced trees (red-black tree, AVL tree); Algorithm design techniques - divide and conquer, dynamic programming, greedy algorithm, amortized analysis; Elementary graph algorithms, minimum spanning tree, shortest path algorithms.

Programming laboratory will be set in consonance with the material covered in lectures. This will include assignments in a programming language like C and C++ in GNU Linux environment.

Texts:

1. T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, Introduction to Algorithms, 2nd Ed.,Prentice-Hall of India, 2007.

References:

1. M. T. Goodrich and R. Tamassia, Data Structures and Algorithms in Java, Wiley, 2006.
2. A.V. Aho and J. E. Hopcroft, Data Structures and Algorithms, Addison-Wesley, 1983.
3. S. Sahni, Data Structures, Algorithms and Applications in C++, 2nd Ed., Universities Press, 2005.

MA542 Differential Equations [4-0-0-8] Prerequisites: Nil

Review of fundamentals of Differential equations (ODEs); Existence and uniqueness theorems, Power series solutions, Systems of Linear ODEs, Stability of linear systems.

First order linear and quasi-linear partial differential equations (PDEs), Cauchy problem, Classification of second order PDEs, characteristics, Well-posed problems, Solutions of hyperbolic, parabolic and elliptic equations, Dirichlet and Neumann problems, Maximum principles, Green's functions.

Texts:

1. E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw Hill, 1990.
2. S. L. Ross, Differential Equations, 3rd Edn., Wiley India, 1984.
3. I. N. Sneddon, Elements of Partial Differential Equations, Dover Publications, 2006.
4. F. John, Partial Differential Equations, Springer, 1982.

References:

1. S. J. Farlow, Partial Differential Equations for Scientists and Engineers, Dover Publications, 1993.
2. E. L. Ince, Ordinary Differential Equations, Dover Publications, 1958.
3. F. Brauer and J. A. Nohel, The Qualitative Theory of Ordinary Differential Equations: An Introduction, Dover Publications, 1969.

MA547 Complex Analysis [3-1-0-8] Prerequisites: Nil

Review of complex numbers; Analytic functions, harmonic functions, elementary functions, branches of multiple-valued functions, conformal mappings; Complex integration, Cauchy's integral theorem, Cauchy's integral formula, theorems of Morera and Liouville, maximum-modulus theorem; Power series, Taylor's theorem and analytic continuation, zeros of analytic functions, open mapping theorem; Singularities, Laurent's theorem, Casorati-Weierstrass theorem, argument principle, Rouche's theorem, residue theorem and its applications in evaluating real integrals.

Texts:

1. R.V. Churchill and J.W. Brown, Complex Variables and Applications, 5th edition, McGraw Hill, 1990.
2. J. H. Mathews and R. W. Howell, Complex Analysis for Mathematics and Engineering, 3rd edition, Narosa, 1998.

References:

1. L. V. Ahlfors, Complex Analysis, 3rd Edn., McGraw Hill, 1979.
2. J. E. Marsden and M. J. Hoffman, Basic complex analysis, 3rd Edn., W. H. Freeman, 1999.
3. D. Sarason, Complex function theory, 2nd Edn., Hindustan book agency, 2007.
4. J.B. Conway, Functions of One Complex Variable, 2nd Edn., Narosa, 1973.

MA590 PROBABILITY THEORY [3-1-0-8] Prerequistes: Nil

Axiomatic definition of probability, probability spaces, probability measures on countable and uncountable spaces, conditional probability, independence; Random variables, distribution functions, probability mass and density functions, functions of random variables, standard univariate discrete and continuous distributions and their properties; Mathematical expectations, moments, moment generating functions, characteristic functions, inequalities; Random vectors, joint, marginal and conditional distributions, conditional expectations, independence, covariance, correlation, standard multivariate distributions, functions of random vectors; Modes of convergence of sequences of random variables, weak and strong laws of large numbers, central limit theorems; Introduction to stochastic processes, definitions and examples.

Texts/References:

1. J. Jacod and P. Protter, Probability Essentials, Springer, 2004.
2. V. K. Rohatgi and A. K. Md. E. Saleh, An Introduction to Probability and Statistics, 2nd Edn., Wiley, 2001.

References:

1. P. G. Hoel, S. C. Port and C. J. Stone, Introduction to Probability Theory, Universal Book Stall, 2000.
2. G. R. Grimmett and D. R. Stirzaker, Probability and Random Processes, 3rd Edn., Oxford University Press, 2001.
3. S. Ross, A First Course in Probability, 6th Edn., Pearson, 2002.
4. W. Feller, An Introduction to Probability Theory and its Applications, Vol. 1, 3rd Edn., Wiley, 1968.
5. J. Rosenthal, A First Look at Rigorous Probability Theory, 2nd Edn., World Scientific, 2006.

MA591 Optimization Techniques [3-1-0-8]

Mathematical foundations and basic definitions: concepts from linear algebra, geometry, and multivariable calculus. Linear optimization: formulation and geometrical ideas of linear programming problems, simplex method, revised simplex method, duality, sensitivity snalysis, transportation and assignment problems. Nonlinear optimization: basic theory, method of Lagrange multipliers, Karush-Kuhn-Tucker theory, convex optimization. Numerical optimization techniques: line search methods, gradient methods, Newton's method, conjugate direction methods, quasi-Newton methods, projected gradient methods, penalty methods.

Texts:

1. N. S. Kambo, Mathematical Programming Techniques, East West Press, 1997.
2. E.K.P. Chong and S.H. Zak, An Introduction to Optimization, 2nd Ed., Wiley, 2010.

References:

1. R. Fletcher, Practical Methods of Optimization, 2nd Ed., John Wiley, 2009.
2. D. G. Luenberger and Y. Ye, Linear and Nonlinear Programming, 3rd Ed., Springer India, 2010.
3. M. S. Bazarra, J.J. Jarvis, and H.D. Sherali, Linear Programming and Network Flows, 4th Ed., 2010. (3nd ed. Wiley India 2008).
4. U. Faigle, W. Kern, and G. Still, Algorithmic Principles of Mathematical Programming, Kluwe, 2002.
5. D.P. Bertsekas, Nonlinear Programming, 2nd Ed., Athena Scientific, 1999.
6. M. S. Bazarra, H.D. Sherali, and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, 3rd Ed., Wiley, 2006. (2nd Edn., Wiley India, 2004).

MA514 Theory of Computation [3-1-0-8] Prerequistes: MA 501 Discrete Mathematics

Alphabets, languages, grammars; Finite automata, regular languages, regular expressions; Context-free languages, pushdown automata, DCFLs; Context sensitive languages, linear bounded automata; Turing machines, recursively enumerable languages; Operations on formal languages and their properties; Chomsky hierarchy; Decision questions on languages; NP-Completeness.

Texts:

1. M. Sipser, Introduction to the Theory of Computation, Thomson, 2004.
2. H. R. Lewis and C. H. Papadimitriou, Elements of the Theory of Computation, PHI, 1981.

References:

1. J. E. Hopcroft and J. D. Ullman, Introduction to Automata Theory, Languages and Computation, Narosa, 1979.
2. Peter Linz, An Introduction to Formal Languages and Automata, Narosa, 2007.
3. D. C. Kozen, Automata and Computability, Springer-Verlag, 1997.
4. D. S. Garey and G. Johnson, Computers and Intractability: A Guide to the Theory of NP-Completeness, Freeman, New York, 1979.

MA543 Functional Analysis [3-1-0-8] Prerequisites: MA541 Real Analysis

Normed linear spaces, Banach spaces; Continuity of linear maps, Hahn-Banach theorem, open mapping and closed graph theorems, uniform boundedness principle; Duals and transposes, weak and weak* convergence, reflexivity; Spectra of bounded linear operators, compact operators and their spectra; Hilbert spaces, bounded linear operators on Hilbert spaces; Adjoint operators, normal, unitary, self-adjoint operators and their spectra, spectral theorem for compact self-adjoint operators.

Texts:

1. B. V. Limaye, Functional Analysis, 2nd edition, Wiley Eastern, 1996.
2. E. Kreyszig, Introduction to Functional Analysis with Applications, John Wiley and Sons, 1978.

References:

1. J.B. Conway, A Course in Functional Analysis, Springer, 1990.

MA572 Numerical Analysis [3-0-2-8] Prerequisites: Nil

Definition and sources of errors, solutions of nonlinear equations; Bisection method, Newton's method and its variants, fixed point iterations, convergence analysis; Newton's method for non-linear systems; Finite differences, polynomial interpolation, Hermite interpolation, spline interpolation; Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature, Richardson extrapolation; Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, multistep methods and stability; Boundary value problems - finite difference method, collocation method.

Texts:

1. D. Kincaid and W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, 3rd Edn., AMS, 2002.
2. K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.

References:

1. S. D. Conte and Carl de Boor, Elementary Numerical Analysis - An Algorithmic Approach, 3rd Edn., McGraw Hill, 1980.

MA571 Numerical Linear Algebra [3-0-2-8] Prerequisites: MA522 Linear Algebra

Fundamentals - overview of matrix computations, norms of vectors and matrices, singular value decomposition (SVD), IEEE floating point arithmetic, analysis of roundoff errors, stability and ill-conditioning; Linear systems - LU factorization, Gaussian eliminations, Cholesky factorization, stability and sensitivity analysis; Jacobi, Gauss-Seidel and successive overrelaxation methods; Linear least-squares - Gram- Schmidt orthonormal process, rotators and reflectors, QR factorization, stability of QR factorization; QR method linear least-squares problems, normal equations, Moore- Penrose inverse, rank deficient least-squares problems, sensitivity analysis. Eigenvalues and singular values - Schur's decomposition, reduction of matrices to Hessenberg and tridiagonal forms; Power, inverse power and Rayleigh quotient iterations; QR algorithm, implementation of implicit QR algorithm; Sensitivity analysis of eiegnvalues; Reduction of matrices to bidiagonal forms, QR algorithm for SVD.

Software Support: MATLAB.

Texts:

1. L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, 1997.
2. D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edn., Wiley, 2002.

References:

1. J.W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997.
2. B. N. Datta, Numerical Linear Algebra and Applications, 2nd Edn., SIAM, 2010.
3. G. H. Golub and C.F.Van Loan, Matrix Computation, 3rd Edn., Hindustan book agency, 2007.

MA573 Numerics of Partial Differential Equations [3-0-2-8] Prerequisites: MA 542 Differential Equations

Finite difference schemes for partial differential equations - explicit and implicit schemes; Consistency, stability and convergence - stability analysis by matrix method and von Neumann method, Lax's equivalence theorem; Finite difference schemes for initial and boundary value problems - FTCS, backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff method, upwind scheme; CFL conditions; Finite element method for ordinary differential equations - variational methods, method of weighted residuals, finite element analysis of one-dimensional problems.

Texts:

1. G. D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 3rd Edn., 1986.
2. J. C. Strikwerda, Finite Difference Schemes and Partial Differential Equations, SIAM, 2004.
3. J. N. Reddy, An Introduction to Finite Element Method, 3rd Edn., McGraw Hill, 2005.

References:

1. L. Lapidus and G. F. Pinder, Numerical Solution of Partial Differential Equations in Science and Engineering, John Wiley, 1982.
2. K. W. Morton and D. F. Mayers, Numerical Solution of Partial Differential Equations, Cambridge University Press, 2nd Edn., 2005.
3. C. Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method, Dover Publications, 2009.

List of Elective courses and Assignments of Semester (odd/even/any):

Courses for **Odd** Semester	Courses for **Even** Semester	Courses for **Any** Semester [If a course in this column is offered in Odd Semseter, then it will not be off red in even semester for the same academic year]
MA424 Advanced Linear Algebra [only for B.Tech]	MA477 Financial Risk Management and Modelling [only for B.Tech]	MA510 Combinatorics
MA476 Portfolio Theory and Performance Analysis [only for B.Tech]	MA504 Combinatorial Optimization	MA545 Complex Dynamics and Fractals
MA502 Graph Theory	MA505 Algebraic Coding Theory	MA549 Topology
MA503 Network Flows Algorithms	MA513 Parallel Computing	MA550 Measure Theory
MA506 Number Theory and Cryptography	MA516 Semantics of Programming Languages	MA561 Fluid Dynamics
		MA564 Fractals and Chaos[Only for M.Sc and B.Tech]

		MA592 Mathematical Finance [Only for M.SC and B.Tech]
MA507Applied Fuzzy Algebra and Fuzzy Logic	MA519 Complexity Theory [Only for M.Sc.]	MA597 Queueing Theory and Applications
MA508 Cryptography	MA544 Wavelets and Applications	MA616 Algorithms for Wireless Ad Hoc and Sensor Networks
MA509Algebraic Number Theory	MA546 Differential Algebraic Equations	MA627 Modular Forms
MA517 Functional and Logic Programming	MA562 Mathematical Modelling and Numerical Simulation	MA640 Topology and Calculus of Surfaces
MA518 Database Management Systems [Only for M.Sc.]	MA576Large Scale Scientific Computation	MA647 Riemann Surfaces[only for M.Sc and Ph.D]
MA523Computer Algebra	MA577 Perturbation Methods	MA649 Harmonic Analysis on Euclidian Spaces [only for Ph.D, M.Sc and B.Tech]
MA548Fourier Theory	MA578 Computational Fluid Dynamics	MA651 Distributed Algorithms
MA563 Calculus of Variations and Optimal Control	MA594 Statistical Decision Theory	MA652 Approximation Algorithms [only for Ph.D, M.Sc and B.Tech]
MA575 Mathematical Methods	MA595Stochastic Programming and Applications	MA665 Stochastic Models in Biology
MA593 Statistical Methods and Times Series Analysis	MA596 Stochastic Calculus for Finance[only for M.Sc]	MA667 Actuarial Mathematics [only for Ph.D, M.Sc and B.Tech]
MA612 Logic Programming	MA598 Mathematics of Financial Derivatives [only for M.Sc]	MA681Applied Stochastic Processes
MA613 Software Defined Networking [only for B.Tech and Ph.D]	MA601 Graphs and Matrices	MA682 Statistical Inference
MA614 Applications of Computational Geometry	MA611 Differential Geometry of Curves and Surfaces	MA686 Random Graphs
MA626 Representation Theory of Finite and Compact Groups	MA621 Rings and Modules	MA688 Stochastic Calculus [Only for M.Sc, M.Tech and PhD]
MA661 Integral Transforms and Integral Equations	MA622 Galois Theory	MA689 Stochastic Integration [Only for B.Tech and PhD]
MA684 Advanced Probability	MA623 Introduction to Algebraic Geometry	MA690 Understanding Statistical Learning Theory [Only for B.Tech, M.Sc, and Ph.D]
	MA624 Introduction to Lie Algebras	MA691 Advanced Statistical Algorithms [Only for B.Tech, M.Sc M.Tech(DS) and PhD]

	MA641 Operator Theory in Hilbert Spaces	
	MA643 Algebraic Topology	
	MA644 DifferentialTopology	
	MA645 Introduction to C*-Algebras	
	MA646 Advanced Operator Theory	
	MA648 Operator Theory on Hardy Spaces[only for M.Sc and Ph.D]	
	MA663 Fractional Calculus and Fractional Differential Equations	
	MA664 Theory and Applications of Sobolev Spaces	
	MA671 Finite Element Methods for Partial Differential Equations	
	MA685 Martingales and Brownian Motion	
	MA687 Generalized Linear Models [Only for B.Tech, M.Tech, and PhD]	

MA424 Advanced Linear Algebra L-T-P-C :3-0-0-6

Review of vector spaces, bases and dimensions, direct sums; Linear transformations, ranknullity theorem, matrix representation of linear transformations, trace and determinant; Eigenvalues and eigenvectors, invariant subspaces, upper triangular matrices, invariant subspaces on real vector spaces, generalized eigenvectors, characteristic and minimal polynomials, triangulation, diagonalization, Jordan canonical form; Norms and innerproducts, orthonormal bases, orthogonal projections, linear functional and adjoints, selfadjoint and normal operators, Schur decomposition, spectral theorems for selfadjoint, unitary and normal operators, positive definite operators, isometry, polar and singular value decompositions.

Texts:

1. S. Axler, Linear Algebra Done Right, 2nd edition, Springer-Verlag, 1997.
2. K. Hoffman and R. Kunze, Linear Algebra, Pearson Education India, 2003.

MA476 Portfolio Theory and Performance Analysis [3-0-0-6]

Mean-variance portfolio theory, asset return, portfolio mean and variance, Markowitz model, efficient frontier calculation algorithm, single-index and multi-index models; Capital Asset Pricing Model (CAPM), Capital market line, pricing model, security market line, systematic and nonsystematic risk, pricing formulas, investment implications, empirical tests, performance evaluation; Multifactor models, CAPM as a factor model, arbitrage pricing theory (APT), multifactor models in continuous time, data statistics, estimation of parameters; Utility functions, risk aversion, utility functions and the mean-variance criterion, linear pricing, portfolio choice, risk neutral pricing; Optimal portfolio growth, continuous-time growth, log-optimal pricing and the Black-Scholes equation; Multiperiod securities, risk neutral pricing, buying price analysis, continuous time evaluation; Fixed Income Security investment, modeling yield curves, managing a bond portfolio, performance analysis.

Texts:

1. D. G. Luenberger, Investment Sciences, Oxford Univ. Press, 1998.
2. J.Cvitanic and F. Zapatero, Introduction to the Economics and Mathematics of Financial Markets, Prentice-Hall of India, 2007.
3. N. Amenc and V. Le Sourd, Portfolio Theory and Performance Analysis, John Wiley & Sons, 2003.

MA477 Financial Risk Management and Modelling [3-0-0-6] Prerequistes: MA373 Financial Engineering II or equivalent

Basics of financial risk management, Identification of major financial risks: interest rate risk, market risk, credit risk, operational risk, liquidity risk, model risk; Basel and Solvency regulations; Market risk: Value-at-Risk (VaR), computation of VaR, coherent measures of risk and risk management; Credit risk: basics of credit risk management, modelling correlated defaults, asset value models, Credit Risk+ model, term structure of default probability, credit derivatives, collateralize debt obligations(CDOs).

Texts/References:

1. J.C. Hull, Risk Management and Financial Institutions, 4th Edition, Wiley, 2016.
2. M.J. Capinski and E. Kopp, Portfolio Theory and Risk Management, Cambridge University Press, 2014
3. C. Bluhm, L. Overbeck and C. Wagner, Introduction to Credit Risk Modeling, 2nd Edition, CRC Press, 2010
4. T.R. Bielecki and M. Rutkowski, Credit Risk: Modeling, Valuation and Hedging, Springer, 2004.

MA502 Graph Theory [3-0-0-6]

Isomorphism, incidence and adjacency matrices, Sperner lemma, Trees,Cayley formula, connector problem, connectivity, constructing reliable communication network, Euler tours, Hamilton cycle, Chinese postman and traveling salesman problems, matchings and coverings, perfect matchings, edge colouring, Vizing Theorem, time table problem, Independent sets, Ramsey theorem, Turan theorem, Schur theorem, vertex colouring, Brook theorem, Hajos conjecture, chromatic polynomials, storage problem, planarity, dual graphs, Euler formula, Kuratowski theorem, five colour theorem, history of four colour theorem, nonhamiltonian planar graphs, planarity algorithm, directed graphs, job sequencing, one way road system, ranking participants in tournaments.

Texts:

1. J. A. Bondy and U. S. R. Murty. Graph Theory with Applications.North-Holland, 1976.
2. J. M. Aldous. Graphs and Applications. Springer, LPE, 2007

MA503 Network Flows Algorithms [3-0-0-6] Prerequisites: MA501 Discrete Mathematics (Graph theory part), MA591 Optimization Techniques

Graph notations and computer representations, Applications to various disciplines, Worst-case complexity. Shortest paths, Label setting and label correcting algorithms, Maximum flows, Augmenting path and pre flow push algorithms, Minimum cost flows. Pseudopolynomial and polynomial time algorithms, Assignments and matching, Bipartite and nonbipartite matchings, Minimum spanning trees, Convex cost flows and generalized flows, Emphasis on real-life time applications of network flows and state-of-the art algorithms.

Texts:

1. R. K. Ahuja, T. L. Magnanti and J. B. Orlin, Network Flows: Theory Applications and Algorithms, Prentice Hall, 1993.
2. L.R. Ford and D.R. Fulkerson, Flows in Networks, Princeton University Press, 1962.
3. A. Dolan, Networks and Algorithms, John Wiley and Sons, 1993.
4. M.N.S. Swamy and K. Thulasiraman, Graphs, Networks and Algorithms, Wiley, 1981.

MA504 Combinatorial Optimization [3-0-0-6] Prerequisites: MA591 Optimization Techniques

Optimization problems, Convex sets and convex functions, Important combinatorial optimization problems, The fundamental algorithms, efficiency and the digital computer. Convex hulls, Polytopes, Facets, Integral polytopes, Total Unimodularity, Total dual integrality, Cutting plane algorithms and bounds, Separation and optimization, Computational complexity. Matroids, Greedy algorithm, Properties, Axioms and constructions of matroids, Matroid Intersection problem, Applications of matroid intersection, Weighted matroid intersection. Heuristics and analysis of heuristics, Heuristics for TSP, Data structure for combinatorial optimization problems.

Texts:

1. R. K. Ahuja, T. L. Magnanti and J. B. Orlin, Network Flows: Theory Applications and Algorithms, Prentice Hall, 1993.
2. G. L. Nemhauser and L.A. Wolsey, Integer and Combinatorial Optimization, John Wiley, 1988.
3. L. R. Foulds, Combinatorial Optimization for Undergraduates, UTM, Springer Verlag, 1984.
4. W. J. Cook, et. al, Combinatorial Optimization, John Wiley and Sons, 1998.

MA505 Algebraic Coding Theory [3-0-0-6] Prerequisites: MA521 Modern Algebra

Binary group codes, Hamming codes, Polynomial codes, Block codes, Linear codes,Generator and check matrices, Sphere packing, Gilbert-Varshamov and Griesmer bounds, Syndrome decoding. The structure of cyclic codes, Reed Mueller codes, Simplex codes. Nonlinear codes, Golay, Hadamard, Justeen, Kerdock, Nordstorm-Robinson codes. Weight distribution of codes, Generalized BCH codes (including the BCH bound and decoding methods), Self-dual codes and invariant theory, MacWilliams identities and Gleason's theorems on self-dual codes, Covering radius problem, Convolutional codes. Reed-Solomon codes, Quadratic-residue codes and perfect codes. The group of a code, permutation and monomial groups, Mathieu groups, General linear and affine groups, Connections with design theory, Steiner systems, Projective and affine planes.

Texts:

1. Hill, A First Course in Coding Theory, Oxford University Press, 1989.
2. V. Pless, Introduction to the Theory of Error-Correcting Codes, 3rd edition, John Wiley, 1998.

MA506 Number Theory and Cryptography L-T-P-C:3-0-0-6 Prerequisites: Nil

Congruence, Chinese Remainder Theorem, Primitive Roots, Quadratic reciprocity, Finite fields, Arithmetic functions Primality Testing and factorization algorithms, Pseudo-primes, Fermat's pseudo-primes, Pollard?s rho method for factorization, Continued fractions, Continued fraction method Hash Functions, Public Key cryptography, Diffie-Hellmann key exchange, Discrete logarithm-based crypto-systems, RSA crypto-system, Signature Schemes, Digital signature standard, RSA Signature schemes, Knapsack problem. Introduction to elliptic curves, Group structure, Rational points on elliptic curves, Elliptic Curve Cryptography. Applications in cryptography and factorization, Known attacks.

Texts:

1. N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.
2. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, Wiley, 2006.
3. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.

References:

1. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.
2. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.
3. J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.
4. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.
5. R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.

MA507 Applied Fuzzy Algebra and Fuzzy Logic L-T-P-C:3-0-0-6 Prerequisites: Nil

Interval numbers, Interval arithmetic, Multilevel interval numbers. Fuzzy numbers, Fuzzy numbers in the set of integers, Arithmetic with fuzzy numbers. Definition of fuzzy sets, Fuzzy sets and fuzzy numbers, Basic operations on fuzzy sets, Extension principle of fuzzy sets. Fuzzy relations, Basic properties of fuzzy relations, Fuzzy relations and approximate reasoning. Fuzzy logic, Linguistic variables, Linguistic modifiers, Truth, Propositions of fuzzy logic, Uncertainty based information, Approximate reasoning. Fuzzy decision making, Multicriteria decision making, Multistage decision making, Fuzzy ranking methods. Fuzzy modeling of control parameters, Washing machine, Fuzzy logic control for a predator-prey system.

Texts:

1. G. J. Klir, U. S. Clair and B. Yuan, Fuzzy Set Theory: Foundation and Application, Prentice Hall, 1997.
2. H. J. Zimmermann, Fuzzy Set Theory and its Applications, 3rd edition, Kluwer Academic, 1992.
3. G. Bojadzieve and M. Bojadzieve, Fuzzy Sets, Fuzzy Logic Applications, World Scientific, 1995.
4. L.H. Tsoukalas and R.E. Uhrig, Fuzzy and Neural Approaches in Engineering, John Wiley and Sons 1997.

MA508 Cryptography L-T-P-C: 3-0-0-6 Prerequisites: Nil

Cryptanalysis; Shannon's Theory; Block Cipher: Data Encryption Standard, Advanced Encryption Standard, Linear and Differential Cryptanalysis; Primality Tests, Factoring Integers, Discrete Logarithm Problem; Public Key Cryptosystem: RSA; Cryptographic Hash Functions; Key Distribution and Key Agreement; Signature Schemes.

References:

1. DOUGLAS R. STINSON, Cryptography: Theory & Practice, Second Edition, CRC Press, 2002.
2. ALFRED J. MENEZES, PAUL C. VAN OORSCHOT and SCOTT A. VANSTONE, Handbook of Applied Cryptography, CRC Press, 2001.
3. JOHANNES. A. BUCHMANN, INTRODUCTION TO CRYPTOGRAPHY, SPRINGER, SEPTEMBER 2000.

MA509 ALGEBRAIC NUMBER THEORY L-T-P-C:3- 0-0-6 Prerequisites: MA521 (MODERN ALGEBRA)

Algebraic numbers, transcendental numbers, minimal polynomial, conjugates. Number fields, primitive element, real and complex embeddings, norm, trace and discriminant. Algebraic integers, ring of integers in a number field, integral basis. Dedekind domain, ideal factorization, fractional ideal, ideal class group. Lattices, Minkowski's theory, computation of class group of number fields. Dirichlet Unit Theorem, fundamental units, units in quadratic fields, Pell's equation. Cyclotomic fields.

Texts:

1. Richard A. Mollin, Algebraic Number Theory, CRC Press, 1999.
2. J. Neukirch, Algebraic Number Theory, Springer, 1999.
3. Stewart and Tall, Algebraic Number Theory and Fermat's Last Theorem, A K Peters, 2002.

References:

1. Alan Baker, A Concise Introduction to Algebraic Number Theory,Cambridge University Press,1994.
2. Janusz G.J., Algebraic Number Fields, GSM, vol-7, AMS, 1996.
3. Marcus, D. A., Number Fields, Springer, 1977.

MA510 Combinatorics [3-0-0-6]Prerequistes: Nil

Counting principles, multinomial theorem, set partitions and Striling numbers of the second kind, permutations and Stirling numbers of the first kind, number partitions, Lattice paths, Gaussian coefficients, Aztec diamonds, formal series, infinite sums and products, infinite matrices, inversion of sequences, probability generating functions, generating functions, evaluating sums, the exponential formula, more on number partitions and infinite products, Ramanujan's formula, hypergeometric sums, summation by elimination, infinite sums and closed forms, recurrence for hypergeometric sums, hypergeometric series, Sieve methods, inclusion-exclusion, Mobius inversion, involution principle, Gessel-Viennot lemma, Tutte mtrix-tree theorem, enumeration and patterns, Polya-Redfield theorem, cycle index, symmetries on N and R, polyominoes

Texts:

1. M. Aigner. A Course in Enumeration. Springer, GTM, 2007.

References:

1. C. Berge. Principles of Combinatorics. Academic Press,1971.
2. J. Riordan. Introduction to Combinatorial Analysis. Dover,2002.
3. M. Bona. Introduction to Enumerative Combinatorics. Tata McGraw Hill, 2007.

MA513 Parallel Computing [2-0-2-6]Prerequistes: Nil

Scope of Parallel Computing - limits to parallelizability, parallel programming platforms; parallel algorithm design - decomposition, task and ineractions; communication models - synchronous and asynchronous; analytical modeling of parallel programs; programming using message passing paradigm and shared address space - threads, MPI, unstructured communications; parallel algorithms and applications - matrix algorithms, sorting, graph algorithms and discrete optimization problems.

Texts/References:

1. A. Grama, G. Karypis, V. Kumar, A. Gupta. Introduction to parallel computing. Addison-Wesley, 2003.
2. J. Ja'Ja'. An introduction to parallel algorithms. Addison-Wesley, 1992
3. R. Greenlaw, H. J. Hoover, W. L. Ruzzo. Limits to parallel computation. Oxford University Press, 1995
4. M. J. Quinn, Parallel Programming in C with MPI and OpenMP, Tata McGraw-Hill, 2003.
5. D. B. Kirk and W.-M. W. Hwu, Programming Massively Parallel Processors, Elsevier, 2013.
6. F. T. Leighton, Introduction to Parallel Algorithms and Architectures: Arrays, Trees, Hypercubes, M. Kaufmann, 1992.

MA516 Semantics of Programming Languages L-T-P-C:3-0-0-6 Prerequisites: MA511 Computer Programming

Elements of a Programming language: Defining Syntax; BNF; Conditional Statements; Iterative Statements; Enumerated and Elementary Data Types; Features of Functional and Imperative languages. Elements of Mathematics: Partial and Multi Functions; Isomorphism, Duality, Zero Objects, Products, Co Products from Category Theory; Term Algebras. Semantics: Operational, Axiomatic and Denotational Semantics of Procedural Languages; Partially Additive Semantics; Recursive Specification; Order Semantics of Recursion; Fixed- Point Semantics; Algebraic Semantics of Abstract Data Types

Texts:

1. Ellis Horowitz, Fundamentals of Programming Languages, Second Edn., Galgotia Publications, 1995.
2. Kenneth Slonneger and Barry L. Kurtz, Formal Syntax and Semantics of Programming Languages: A Laboratory Based Approach, Addison-Wesley Publishing Company, 1995.
3. Ernest G. Manes and Michael A. Arbib, Algebraic Approaches to Program Semantics, Texts and Monographs in Computer Science, Springer-Verlag, 1986.

References:

1. Carlo Ghezzi and Mehdi Jazayeri, Programming Language Concepts, Third Edn., John Wiley & Sons, 1998.
2. Ravi Sethi, Programming Languages: Concepts and Constructs, Addison-Wesley Publishing Company, 1989.
3. Glynn Winskel, The Formal Semantics of Programming Languages: An Introduction, The MIT Press, 1993.
4. Hartmut Ehrig and Bernd Mahr, Fundamentals of Algebraic Specification 1: Equations and Initial Semantics, Springer-Verlag, 1985.

MA517 FUNCTIONAL AND LOGIC PROGRAMMING (3 0 0 6) Prerequisites: MA501 and MA511; or equivalent

Functional programming: functions as first class objects, laziness, data-types and pattern matching, classes and overloading, side-effects, description in languages like ML or Haskell; Lambda calculus: syntax, conversions, normal forms, Church-Rosser theorem, combinators; Implementation issues: graph reduction; Logic programming: logic and reasoning, logic programs, Prolog syntax, Horn clauses, resolution-refutation, constraint logic programming.

Texts:

1. S. Thompson, Haskell: The Craft of Functional Programming, 2nd Edition, Addison- Wesley, 1999.
2. S. L. Peyton Jones, The Implementation of Functional Programming Languages, Prentice Hall, International Series in Computer Science, 1987.
3. L. Stirling and E. Shapiro, The Art of Prolog: Advanced Programming Techniques, 2nd Edition, MIT Press, 1994.

References:

1. C. Reade, Elements of Functional Programming, Addison-Wesley, 1989.
2. H. Barendregt, The Lambda Calculus: Its Syntax and Semantics, North Holland, 1984.
3. J. W. Lloyd, Foundations of Logic Programming, Springer Verlag, 1987.

MA518 Database Management Systems (2 0 2 6) Prerequisites: MA511 Computer Programming and MA512 Data Structures and Algorithms or equivalent

The course aims to introduce database management systems from application perspective. This is expected to helpful for M.Sc. (Mathematics and Computing) students who wish to pursue career in software industry.

Data models with emphasis on the relational model; Database design with E-R model; From E-R model to relational database design; Relational algebra and calculus; SQL queries, constraints, triggers; Database application development: JDBC, SQLJ, Stored procedures; Internet applications: HTML, XML, Three-Tier application architecture; Schema refinement and normal forms; Physical database design and tuning; Security authorization.

Texts:

1. R. Ramakrishnan and J. Gehrke, Database Management Systems, 3rd Edition, McGraw Hill, 2003
2. P. DuBois, MySQL, 4th Edition, Addison Wesley, 2009.

References:

1. A. Silberschatz, H.F. Korth and S. Sudarshan, Database System Concepts, 5th Edition, McGraw Hill, 2006.
2. S. Feuerstein and B. Pribyl, Oracle Pl/SQl Programming, 5th Edition, O'Reilly, 2009.
3. J. Greenspan and B. Bulger, MySQL/PHP Database Applications, M&T Books, 2008.

MA519 Complexity Theory [3-0-0-6]Prerequistes: MA352 or equivalent

Time and Space complexity, various complexity classes, oracle Turing machine, hierarchy theorems, relations among complexity measures, Savitch's theorem, Borodin's Gap theorem, Blum's speed-up theorem, the union theorem, axiomatic complexity theory, intractable problems, PSPACE-completeness, EXPSPACE-completeness, QBF problem, provably intractable problems, P = NP?, alternating time and space.

Texts:

1. J. E. Hopcroft and J. D. Ullman, Introduction to Automata Theory, Languages and Computation, Narosa, 1979.
2. M. Sipser, Introduction to the Theory of Computation, Thomson Asia Pte Ltd., 1997.

References:

1. D. Bovet and P. Crescenzi, Introduction to the Theory of Complexity, Prentice Hall, 1993.
2. D. Kozen, Theory of Computation, Springer, 2006
3. D. S. Garey and G. Johnson, Computers and Intractability: A Guide to the Theory of NP-Completeness, Freeman, New York, 1979.
4. C. H. Papadimitriou, Computational Complexity, Addison-Wesley, 1994.
5. J. L. Balcazar, J. Diaz, J. Gabarro, Structural Complexity, 2nd Ed, Vol 1, Springer-Verlag, 1995.

MA523 COMPUTER ALGEBRA L-T-P-C: 3-0- 0-6 Prerequisites: MA501 Discrete Mathematics & MA521 Modern Algebra

Algebraic numbers, Primes and factoring, Trapdoors and public key, Pseudo-random numbers. The finite Fourier transforms. The fast Fourier transform., Polynomial rings in several variables, Complexity with respect to multiplication, Shift registers and coding, Finite Boolean algebras, Equivalence classes of switching functions, Monoids and automata.

Texts/References:

1. L. Garding and T. Tambour, Algebra for Computer Science, Narosa, 1992
2. W. Burnside, The Theory of Groups of Finite Order, Cambridge University Press, 1987
3. W. Kuich and K. N. Saloma, Semirings, Automata, Languages, Springer Verlag, 1985
4. J. J. Canon, A Language for Group Theory, (Preprint) University of Sydney, 1982.

MA544 Wavelets and Applications L-T-P-C:3-0-0-6 Prerequisites: MA543 Functional Analysis

Reviews of Fourier analysis and LP spaces. Wavelets and atomic decomposition of functions, Multiresolution signal decomposition, Multiresolution analysis and the construction of wavelets, Examples of wavelets,QMF and fast wavelet transform, Localization, Regularity and approximation properties of wavelets. Construction of compactly support wavelets, Orthonormal bases of compactly supported wavelets, Wavelets sampling techniques, Convergence of Wavelet expansion, Time-frequency analysis for signal processing, Applications of wavelets in image and signal processing.

Software Support: MATLAB, MATHEMATICA

Texts/References:

1. Y. Meyer, Wavelets: Algorithm and Application , SIAM, 1993.
2. E. Aboufadel and S. Schlicker, Discovering Wavelets , John Wiley and Sons, 1999.
3. G. Kaiser, A Friendly Guide to Wavelets, Birkhauser, 1994.

MA 545 Complex Dynamics and Fractals L-T-P-C:3-0-0-6 Prerequisites: Nil

Classical Fractals, Cantor set, Sierpinski triangle, Von Koch curve, Hilbert and Peano curves, Weierstrass function. Self-similarity, Scaling, Similarity dimension, Box-counting dimension, Information dimension, Capacity dimension. Foundations of iterated function systems (IFS), Classical fractals generated by IFS, Contractions mapping principle, Collage theorems, Fractal image compression, Image encoding and decoding by IFS. Iteration of quadratic polynomials, Julia sets, Fatou sets, Mandelbrot set, Characterization of Julia sets, Dynamics of functions ez , sin z and cos z, Bifurcation and chaotic burst.

Software Support: MATLAB, MATHEMATICA, GNUPLOT

Texts / References:

1. M. F. Barnsley, Fractals Everywhere , 2nd edition, Academic Press, 1995.
2. Ning Lu, Fractal Imaging, Academic Press, 1997.
3. M. J. Turner et. al, Fractal Geometry in Digital Imaging, Academic Press, 1998.
4. A. F. Beardon, Iteration of Rational Functions, Springer Verlag, 1991.
5. L. Carleson and T.W. Gamelin, Complex Dynamics, Springer Verlag, 1993.

MA 546 Differential Algebraic Equations L-T-P-C:3-0-0-6 Prerequisites: Nil

Classification of DAEs, Solvability and Index, Linear constant coefficient DAEs, Linear time varying DAEs, Nonlinear systems, Index reduction and constraint stabilization. Runge-Kutta method for DAEs, Classes of implicit Runge-Kutta methods, Convergence analysis for Index 1, Index 2, and Index 3 systems. Solution of nonlinear systems by Newton's method, Local error estimation. Multistep methods, BDF convergence, Semi explicit index 1 systems, Fully implicit index 1 systems, Semi explicit index 2 systems, Index 3 systems of Hessenberg form, BDF methods, Stiff Problems and applications.

Software Support: DASSL, RADAU5

Texts / References:

1. E. Hairer, C. Lubich and M. Roche, The Numerical Solution of Differential Algebraic Systems by Runge-Kutta Methods, Springer Verlag, 1989.
2. K.E. Brenan, S. L. Campbell and L. R. Petzold, Numerical Solution of Initial Value Problems in Differential Algebraic Equations , North Holland, 1989.

MA548 Fourier Theory 3-0-0-6 Prerequisites: Nil

Fourier series: Definition, examples and uniqueness of Fourier series. Convolution, Cesaro summability and Abel summability, the Poisson kernel and Dirichlet's problem in the unit disc. Mean-square and pointwise convergence of Fourier series, applications of Fourier series.

Fourier transform: Elementary theory of Fourier transforms, the Schwartz space, the Fourier inversion, the Plancherel formula. Theory of distributions, Fourier transform of a tempered distribution. Poisson summation formula, Heisenberg's uncertainty principle, Paley-Wiener theorem, Wiener's theorem, Wiener-Tauberian theorem.

Texts / References:

1. W. Rudin, Functional Analysis, Tata McGraw Hill, 1974.
2. Elias M. Stein and Rami Shakarchi, Fourier Analysis an Introduction, Princeton University Press, 2003.

MA549 Topology 3-0-0-6 Prerequisites: Nil

Topological spaces, Basis for a topology, Limit points and closure of a set, Continuous and open maps, Homeomorphisms, Subspace topology, Product and quotient topology. Connected and locally connected spaces, Path connectedness, Components and path components, Compact and locally compact spaces, One point compactification. Countability axioms, Separation axioms, Urysohn s Lemma, Urysohn s metrization theorem, Tietze extension theorem, Tychonoff s theorem, Completely Regular Spaces, Stone-Cech Compactification.

Texts:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
2. James R. Munkres, Topology, Second Edition, Prentice Hall, 1999.

References:

1. Stephan Willard, General Topology, Dover, 2004.
2. Klaus Janich, Topology, Springer, UTM, 1984.
3. James Dugundji, Topology, McGraw Hill, 1966.

MA 550 MEASURE THEORY (3 0 0 6) Prerequisites: Nil

Algebras and ólgebras, measures, outer measures, measurable sets, Lebesgue measure and its properties, non-measurable sets, measurable functions and their properties, Egoroff s theorem, Lusin s theorem; Lebesgue Integration: simple functions, integral of bounded functions over a set of finite measure, bounded convergence theorem, integral of nonnegative functions, Fatou s lemma, monotone convergence theorem, the general Lebesgue integral, Lebesgue convergence theorem, change of variable formula; Differentiation and integration: functions of bounded variation, differentiation of an integral, absolute continuity; Signed and complex measures, Radon-Nikodym theorem, Lp -spaces and their dual; Product measures, constructions, Fubini s theorem and its applications.

Texts:

1. D. L. Cohn, Measure Theory, 1st Edition, Birkhauser, 1994.
2. G. de Barra, Measure Theory and Integration, New Age International, 1981.

References:

1. M. Capinski and E. Kopp, Measure, Integral and Probability, 2nd Edition, Springer, 2007.
2. H. L. Royden, Real Analysis, 3rd Edition, Prentice Hall/Pearson Education, 1988.

3. I. K. Rana, An Introduction to Measure and Integration, Narosa, 1997.

MA561 Fluid Dynamics [3-0-0-6] Prerequisites: Nil

Review of gradient, divergence and curl. Elementary idea of tensors. Velocity of fluid, Streamlines and path lines, Steady and unsteady flows, Velocity potential, Vorticity vector, Conservation of mass, Equation of continuity. Equations of motion of a fluid, Pressure at a point in fluid at rest, Pressure at a point in a moving fluid, Euler's equation of motion, Bernoulli's equation. Singularities of flow, Source, Sink, Doublets, Rectilinear vortices. Complex variable method for two-dimensional problems, Complex potentials for various singularities, Circle theorem, Blasius theorem, Theory of images and its applications to various singularities. Three dimensional flow, Irrotational motion, Weiss's theorem and its applications. Viscous flow, Vorticity dynamics, Vorticity equation, Reynolds number, Stress and strain analysis, Navier-Stokes equation, Boundary layer Equations

Texts:

1. N. Curle and H. Davies, Modern Fluid Dynamics, Van Nostrand Reinhold, 1966.
2. L. M. Milne Thomson, Theoretical Hydrodynamics, Macmillan and Co., 1960.
3. G. K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 1993.
4. F. Chorlton, A Text Book of Fluid Dynamics, Von Nostrand Reinhold/CBS, 1985.
5. A. R. Patterson, A First Course in Fluid Dynamics, Cambridge University Press, 1992.

MA562 Mathematical Modelling and Numerical Simulation [3-0-0-6] Prerequisites: Nil

Model and its different types, Finite models, Statistical models, Stochastic models, Formulation of a model, Laws and conservation principles, Discrete and continuous models, Manipulation into its most respective form, Evaluation of a model. Case studies, Continuum model, Transport phenomena, Diffusion and air pollution models, Microwave heating, Communication and Information technology.

Software Support : MATHEMATICA, LSODE, GNUPLOT, MATLAB.

Texts:

1. R. Aris, Mathematical Modelling Techniques, Dover, 1994.
2. C. L. Dym and E. S. Ivey, Principles of Mathematical Modelling, Academic Press, 1980.
3. M. S. Klamkin, Mathematical Modelling: Classroom Notes in Applied Mathematics, SIAM, 1986.
4. A. Friedman and W. Littman, Industrial Mathematics for Undergraduates, SIAM, 1994.
5. Y. C. Fung, A First Course in Continuum Mechanics, Prentice Hall, 1969.
6. E. N. Lightfoot, Transport Phenomenon and Living Systems, Wiley, 1974.
7. M. Braun, C. S. Coleman and D. A. Drew, Differential Equation Models, Modules in Applied Mathematics, Volume1, Springer Verlag, 1978.

MA 563 Calculus of Variations and Optimal Control L-T-P-C:3-0-0-6 Prerequisites: MA542 Differential Equations

The concept of variation and its properties, Variational problems with fixed boundaries, The Euler equation, Variational problems in parametric form. Variational problems with moving boundaries, Reflection and refraction extremals. Sufficient conditions for an extremum, Canonical equations and variational principles, Complementary variational principles, The Hamilton-Jacobi equation. Direct methods for variational problems, Rayleigh-Ritz method, Galerkin method. Introduction to optimal control problems, Controllability and optimal control, Isoperimetric problems, Bolza problem, Optimal time of transit, Rocket propulsion problem, Linear autonomous time-optimal control problem, Existence theorems for optimal control problems, Necessary conditions for Optimal controls, The Pontryagin maximum principle.

Texts / References:

1. A. S. Gupta, Calculus of Variation with Applications, Prentice-Hall, India, 1997.
2. J. Macki and A. Strauss, Introduction to Optimal Control Theory, UTM, Springer, 1982.
3. G. M. Ewing, Calculus of Variations with Applications, Dover, 1985.
4. H. Sagan, Introduction to Calculus of Variations, Dover, 1967.
5. J. L. Troutman, Variational Calculus and Optimal Control, 2nd edition, Springer Verlag, 1996.

MA564 Fractals and Chaos [3-0-0-6] Prerequisites: Nil

Fractals: Cantor set, Sierpinski triangle, Von Koch curve, Hilbert and Peano curves, Weierstrass function. Self-similarity, Scaling, Similarity dimension, Box-counting dimension, Information dimension, Capacity dimension. Foundations of iterated function systems (IFS), Classical fractals generated by IFS, Contractions mapping principle, Collage theorem, some applications of Fractals.

Chaos: One dimensional maps, periodic points, sensitive dependence on initial conditions, chaos, Sarkoviskii theorem, Logistic map, Henon map. Dynamics of complex polynomials, Julia sets, Fatou sets, Mandelbrot set, characterization of Julia sets. Dynamics of Newton method.

Texts:

1. M. F. Barnsley, Fractals Everywhere, Second Edition, Academic Press, 1995.
2. R. L. Devaney, An Introduction to Chaotic Dynamical Systems, Second Edition, Addision-Wesley, 1989.

References:

1. K. Falconer, Fractal Geometry – Mathematical Foundations and Applications, Third Edition, Wiley, 2013.

MA575 Mathematical Methods [3-0-0-6] Prerequisites: Nil

Power series solutions, Bessel functions, Modified Bessel functions, Legendre polynomial, Laguerre polynomial, Chebyshev polynomial, Hermite polynomials: recurrence relations, orthogonality. Concept and calculation of Green's function, Properties, Green's function method for ordinary and partial differential equations. Fourier Series, Fourier Cosine series, Fourier Sine series, Fourier integrals. Fourier transform, Laplace transform, Hankel transform, finite Hankel transform, Mellin transform. Solution of differential equations by integral transform methods. Construction of the kernels of integral transforms on a finite interval through Sturm-Liouville problem. Occurrence of integral equations, Regular and singular integral equations: Volterra integral equations, Fredholm integral equations, Volterra and Fredholm equations with different types of kernels.

Texts/References:

1. G. N. Watson, A Treatise on the Theory of Bessel Functions, Cambridge University Press, 1944.
2. G. F. Roach, Green's Functions, Cambridge University Press, 1995.
3. A. D. Poularikas, The Transforms and Applications Handbook, CRC Press, 1996.
4. L. Debnath and D.D. Bhatta, Integral Transforms and Their Applications, Chapman and Hall/CRC, 2011.
5. J. W. Brown and R. Churchill, Fourier Series and Boundary Value Problems, McGraw Hill, 1993.
6. F.G Tricomi, Integral Equations, Dover Publications Inc. New York, 1985.

MA576 Large Scale Scientific Computation [3-0-0-6] Prerequisites: MA571 Scientific Computing, MA574 Numerical Linear Algebra

Large sparse linear systems, Storage schemes, Review of stationary iterative process, Krylov subspace methods, Conjugate gradients(CG), BiCG, MINRES and GMRES, The Lanczos iteration, From Lanczos to Gauss quadrature, Preconditioning, Error bounds for CG and GMRES, Effects of finite precision arithmetic, Multigrid methods, Multigrid as a preconditioner for Krylov subspace methods. Nonlinear systems, Newton's method and some of its variants, Newton GMRES, Continuation methods, Conjugate direction method, Davidon-Fletcher-Powell Algorithms.

Software Support: HOMPACK, LAPACK.

System Support: PARAM.

Texts:

1. J. M. Ortega and W. C. Rheinboldt, Iterative Solution of Nonlinear Equations in Several Variables, Academic Press, 1970.
2. C. T. Kelly, Iterative Methods for Linear and Nonlinear Equations, SIAM, Philadelphia, 1995.
3. A. Greenbaum, Iterative Methods for Solving Linear Systems, SIAM, Philadelphia, 1997.

4. O. Axelsson, Iterative Solution Methods, Cambridge University Press, 1994.
5. P. Wesseling, An Introduction to Multigrid Methods, John Wiley & Sons, 1992.
6. C. W. Ueberrhuber, Numerical Computation: Methods, Software and Analysis, Springer Verlag, 1997.
7. I. S. Duff, A.M.Erisman and J. K. Reid, Direct Methods for Sparse Matrices, Oxford University Press, 1986.

MA577 Perturbation Methods [3-0-0-6]

Asymptotic expansion and approximations, Asymptotic solution of algebraic and transcendental equations, Introduction to the asymptotic solution of differential equations. Regular Perturbations, Perturbed second order differential equations, Dimensional analysis, Initial and boundary value problems, Partial differential equations, Error estimation. Multiple scales, Overview of multiple scales and averaging, The first order two-scale approximation, Higher order approximations. Methods of WKB type, Introductory examples, The formal WKB expansion without turning points, Ray methods

Texts/References:

1. 1. J. A. Murdock, Perturbations Theory and Methods, John Wiley and Sons, 1991.
2. 2. M. H. Holmes, Introduction to Perturbation Methods, Springer Verlag, 1995.

MA578 Computational Fluid Dynamics [3-0-0-6] Prerequisites: MA561 Fluid Dynamics

Incompressible plane flows, Stream function and vorticity equations, Conservative form and normalizing systems, Method for solving vorticity transport equation, Basic finite difference forms, Conservative property, Convergence and stability analysis, Explicit and implicit methods, Stream function equation and boundary conditions, Schemes for advective diffusion equation, Upwind differencing and artificial vorticity, Solution for primitive variables.

Software Support: CFD Software Packages.

Texts:

1. C. A. J. Fletcher, Computational Techniques for Fluid Dynamics, Volume 1 & 2, Springer Verlag, 1992.
2. C. Y. Chow, Introduction to Computational Fluid Dynamics, John Wiley, 1979.
3. M. Holt, Numerical Methods in Fluid Mechanics, Springer Verlag, 1977.
4. H. J. Wirz and J. J. Smolderen, Numerical Methods in Fluid Dynamics, Hemisphere, 1978.
5. D. A. Anderson, J. C. Tannehill and R. H. Pletcher, Computational Fluid Dynamics and Heat Transfer, McGraw Hill, 1984.

MA 592 Mathematical Finance [3-0-0-6] Prerequisites: Nil

Financial markets and financial instruments; Risk-free and risky assets, discrete time binomial and continuous time geometric Brownian motion models for risky assets; Financial derivatives, forwards and futures, options, swaps; No-arbitrage principle; Properties of forwards and futures; General properties of options, pricing of options by Cox-Ross-Rubinstein Formula and Black-Scholes formula; Properties of swaps; Financial risk management, dynamic hedging of bonds using Duration and Convexity, hedging of options positions, Value-at-Risk.

Texts:

1. M. Capinski and T. Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, Springer Undergraduate Mathematics Series, 2nd Edition, Springer, 2010.

References:

1. J. C. Hull, Options, Futures and Other Derivatives, 10th Edition, Pearson, 2018.
2. J. Cvitanic and F. Zapatero, Introduction to the Economics and Mathematics of Financial Markets, Prentice-Hall of India, 2007.

MA 593 Statistical Methods and Time Series Analysis L-T-P-C:3-0-0-6 Prerequisites: MA592 Probability, Random Processes and Statistical Inference

Review of sampling distributions. Point and interval-estimation, Hypothesis testing, Likelihood ratio procedure, Bayesian methods. Introduction to decision theory. Regression methods, Linear, Multilinear and polynomial regression. Model checking. Time series analysis, Introduction to autocorrelation function, linear stationary models like autoregressive, integrated moving average processes, Yule-Walker equations and partial auto correlations, Forecasting.

Software Support: Statistical packages like SAS and SPSS.

Texts / References:

1. A. B. Bowker and G. J. Libermann, Engineering Statistics, Asia, 1972.
2. N. L. Johnson and F. C. Xeen Leone, Statistics and Experimental Design in Engineering and the Physical Sciences, Volumes 1 and 2, 2nd edition, Wiley, 1977.
3. C. Chatfield, The Analysis of Time Series: An Introduction, Chapman and Hall, 1984.
4. G. E. P. Box and G. M. Jenkins, Time Series Analysis Forecasting and Control, Holden-Day, 1976.

MA594 Statistical Decision Theory [3-0-0-6] Prerequisites: MA592 Probability and Statistical Inference

Decision functions, Risk functions, Utility and subjective probability, Randomization, Optimal decision rules. Admissibility and completeness, Existence of Bayes decision rules, Existence of a minimal complete class, Essential completeness of the class of nonrandomized rules. The minimax theorem. Invariant statistical decision problems. Multiple decision problems. Sequential Decision problems.

Texts:

1. J. O. Berger, Statistical Decision Theory: Foundations, Concepts and Methods, Springer Verlag, 1980.
2. T. S. Ferguson, Mathematical Statistics, Academic Press, 1967.

MA 595 Stochastic Programming and Applications L-T-P-C:3-0-0-6 Prerequisites: MA592 Probability, Random Processes and Statistical Inference

Quadratic and nonlinear programming solution methods applied to chance constrained programming problems. Stochastic linear and nonlinear programming problems arising in inventory control and other industrial applications. Queuing models of computer networks, Information processing under uncertainty, Two stage and multi stage solution techniques. Use of Monte carlo, Probabilistic and heuristic algorithms, Genetic algorithms and neural networks for adaptive optimization.

Texts / References:

1. J. K. Sengupta, Stochastic Optimizations and Economic Models, Dordrecht Reidel, 1986.
2. Yu. Ermoliev and R. J. B. Wets, Numerical Techniques for Stochastic Optimization, Springer Verlag, 1988.
3. K. Schittkowski, More Test Examples of Nonlinear Programming Codes , Springer Verlag, 1987.
4. Z. Michaeleawicz, General Algorithms + Data Structures =Evolution Program, Springer Verlag, 1992

MA 596 STOCHASTIC CALCULUS FOR FINANCE L-T-P-C:3-0-0-6 Prerequisites: Nil

Basic ideas of hedging and pricing by arbitrage. Basic concepts from probability theory and stochastic processes, conditional expectation, martingales, random walk, Markov processes, Brownian motion. Stochastic integration, Itôintegral, Itôformula. Stochastic differential equations. Risk-neutral pricing, Black-Scholes-Merton option pricing model, Girsanov s Theorem, American derivative securities, term-structure models. Jump processes and their application to option pricing.

Texts:

1. S.E. Shreve, Stochastic Calculus for Finance I: The Binomial Asset Pricing Model, Springer, 2005.
2. S.E. Shreve, Stochastic Calculus for Finance II: Continuous-Time Models, Springer, 2005.
3. J.M. Steele, Stochastic Calculus and Financial Applications, Springer, 2001.

References:

1. T. Mikosh, Elementary Stochastic Calculus, with Finance in View, World Scientific, 1998.
2. F.C. Klebaner, Introduction to Stochastic Calculus with Applications, World Scientific, 2005.

MA 597 QUEUEING THEORY AND APPLICATIONS (3 0 0 6) Prerequisites: Nil

Review of probability, random variables, distributions, generating functions; Poisson, Markov, renewal and semi-Markov processes; Characteristics of queueing systems, Little s law, Markovian and non-Markovian queueing systems, embedded Markov chain applications to M/G/1, G/M/1 and related queueing systems; Networks of queues, open and closed queueing networks; Queues with vacations, priority queues, queues with modulated arrival process, discrete time queues, introduction to matrix-geometric methods, applications in manufacturing, computer and communication networks.

Texts:

1. D. Gross and C. Harris, Introduction to Queueing Theory, 3rd Edition, Wiley, 1998 (WSE Edition, 2004)
2. L. Kleinrock, Queueing Systems, Vol. 1: Theory, John Wiley, 1975.
3. J. Medhi, Stochastic Models in Queueing Theory, 2nd Edition, Academic Press, 2003 (Elsevier India Edition, 2006).

References:

1. J.A. Buzacott and J.G. Shanthikumar, Stochastic Models of Manufacturing Systems, Prentice Hall, 1992.
2. R. B. Cooper, Introduction to Queueing Theory, 2nd Edition, North-Holland, 1981.
3. L. Kleinrock, Queueing Systems, Vol. 2: Computer Applications, John Wiley, 1976.
4. R. Nelson, Probability, Stochastic Processes, and Queueing Theory: The Mathematics of Computer Performance Modelling, Springer, 1995.
5. E. Gelenbe and G. Pujolle, Introduction to Queueing Networks, 2nd Edition, Wiley, 1998.

MA 598 MATHEMATICS OF FINANCIAL DERIVATIVES (3 0 0 6) Prerequisites: Nil

Probability, random variables, probability distributions, expectations, martingales, Brownian motion, Itôtegral, Itôformula; Financial markets and financial instruments, forward and futures contracts and determination of their prices, options, mechanism of options markets, put-call parity, European and American options, risk-neutral valuation, Cox-Ross-Rubinstein model, Black-Scholes-Merton model; Numerical methods for European and American options.

Texts:

1. P. Wilmott, S. Howison and J. Dewynne, The Mathematics of Financial Derivatives, Cambridge University Press, 1995.
2. S. Roman, Introduction to the Mathematics of Finance: From Risk Management to Options Pricing, Springer, 2004.
3. J. C. Hull, Options, Futures and Other Derivatives, 6th Edition, Prentice Hall of India/Pearson Education, 2006.

References:

1. M. Capinski and T. Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, Springer, 2005.
2. D. Higham, An Introduction to Financial Option Valuation: Mathematics, Stochastics and Computation, Cambridge University Press, 2004.

MA 601 Graphs and Matrices (3-0-0-6)

Matrices, Eigenvalues of symmetric matrices, Graphs. Incidence Matrix, Rank, Minors, 0-1 Incidence matrix, Matchings in bipartite graphs. Adjacency Matrix, Eigenvalues of some graphs, Determinant, Bounds, Energy of a graph, Antiadjacency matrix of a directed graph, Nonsingular trees. Laplacian Matrix, Basic properties, Computing Laplacian eigenvalues, Matrix-tree theorem, Bounds for Laplacian spectral radius, Edge-Laplacian of a tree.Cycles and Cuts, Fundamental cycles and fundamental cuts, Fundamental matrices, Minors.Regular Graphs, Perron Frobenius theory, Adjacency algebra of a regular graph, Complement and line graph of a regular graph, Strongly regular graphs and friendship theorem, Graphs with maximum energy.Line Graph of a Tree, Block graphs, Signless Laplacian matrix, Nullity of the line graph of a tree. Algebraic Connectivity, Classification of trees, Monotonicity properties of Fiedler vector, Bounds for algebraic connectivity. Distance Matrix of a Tree, Distance matrix of a graph, Distance matrix and Laplacian of a tree, Eigenvalues of the distance matrix of a tree. Positive Definite Completion Problem, Nonsingular completion, Chordal graphs, Positive definite completion.

Texts/References:

1. R. B. Bapat, Graphs and Matrices, Texts and Readings in Mathematics, Hindustan Book Agency, New Delhi, 2010.
2. D. M. Cvetkovic, M. Doob and H. Sachs, Spectra of Graphs: Theory and Applications, Academic Press, 1980.
3. C. Godsil and G. Royale, Algebraic Graph Theory, Graduate Texts in Mathematics 207, Springer, 2001.
4. N. Biggs, Algebraic Graph Theory, Cambridge University Press, 1974.

MA 611 DIFFERENTIAL GEOMETRY OF CURVES AND SURFACES (3-0-0-6) Prerequisites: MA541 or equivalent

Local theory of plane and space curves, Curvature and torsion formulas, Serret-Frenet formulas, Fundamental Theorem of space curves. Regular surfaces, Change of parameters, Differentiable functions, Tangent plane, Differential of a map. First and second fundamental form. Orientation, Gauss map and its properties, Euler's Theorem on principal curvatures. Isometries, and Gauss' Theorema Egregium. Parallel transport, Geodesics, Gauss-Bonnet theorem and its applications to surfaces of constant curvature. Hopf-Rinow's theorem, Bonnet's theorem, Jacobi fields, Theorems of Hadamard. Riemann's Habilitationsvortrag.

Texts/References:

1. Manfredo P. Do Carmo, Differential Geometry of Curves and Surfaces, Prentice Hall, 1976.
2. John McCleary, Geometry from a Differentiable Viewpoint, Cambridge University Press, 1994.
3. Michael Spivak, A Comprehensive Introduction to Differential Geometry, Publish or Perish, 1994.
4. Barret O'Neill, Elementary Differential Geometry, Academic Press, Second Edition, 1997
5. Carl Friedrich Gauss, General Investigations of Curved Surfaces, Edited with an Introduction and Notes by Peter Pesic, Dover 2005.
6. Andrew Pressley, Elementary Differential Geometry, Springer 2002.

MA612 Logic Programming [2-0-2-6]

Logic and reasoning; Predicate logic - terms, formulae and clauses, clausal form of formulae, types of clauses, Horn clauses, substitution, unification algorithm, resolution, SLD-refutation; Introduction to Prolog, structure of logic programs, syntax and meaning, controlling backtracking, negation in logic programs and implementation issues, lists, operators, arithmetic, input and output, built-in predicates, operations on data structures, meta-programming; Constraint logic programming.

Texts/References:

1. I. Bratko, Prolog: Programming for Artificial Intelligence, 3rd Edn., Pearson, 2001.
2. M. Ben-Ari, Mathematical Logic for Computer Science, 2nd Edn., Springer, 2003.
3. J. W. Lloyd, Foundations of Logic Programming, Springer Verlag, 1987.
4. T. Fruhwirth, H. Wiesenthal, and S. Abdennadher, Essentials of Constraint Programming, 1st Edn.,Springer, 2003.
5. K. R. Apt, and M. Wallace, Constraint Logic Programming Using Eclipse, Cambridge University Press, 2007.

MA613 Software Defined Networking [3-0-0-6] Prerequisites: CS348 or Undergraduate Computer Networks course

Preamble / Objectives (Optional): Software Defined Networking (SDN) has emerged as a key technology to help address longstanding issues in network management and deploying new services. The course will focus on the present developments in SDN and how these technologies could form the basis of future Internet. The course will introduce the SDN framework, the main concepts, protocols and applications of SDN. With this target to motivate students towards the development of a new networking architecture, the course will cover some of the mainstream SDN controllers used in production level as well as academic research. SDN real use cases in educational campuses but also in other environments such as data centers, carrier networks etc. The later part of the course will study the relationship between SDN and network virtualization. The course will also study the framework for enabling security control in Open Flow networks

Course Content/ Syllabus: History and Evolution of Software Defined Networking (SDN); Control and Data Plane Separation: Concepts, Advantages and Disadvantages; The Open Flow protocol; Control Plane: Overview, study of existing SDN Controllers - Floodlight, Open Daylight, SDN Applications (traffic engineering, software defined storage); Use Cases of SDNs: Data Centers, Wide Area Networks, Service Provider and Carrier networks, Optical Networks; Network Virtualization: Concepts, Applications, Network Functions Virtualization (NFV), SDN vs. NFV; SDN Security

References:

1. Thomas D. Nadeau and Ken Gray, SDN: Software Defined Networks: An Authoritative Review of Network Programmability Technologies, O'Reilly Media, August, 2013.
2. Paul Goransson and Chuck Black, Software Defined Networks: A Comprehensive Approach, 2nd Edition, Morgan Kaufmann, 2014.
3. Oswald Coker and Siamak Azodolmolky, Software Defined Networking with Open Flow, Packt Publishing Limited, 2nd edition, 2017.
4. Patricia A Morreale and James M. Anderson, Software Defined Networking: Design and Deployment, CRC Press, 2014.
5. Vishal Shukla, Introduction to Software Defined Networking - Open Flow & VxLAN, Create space Independent Publishing Platform, 2013.

MA614 Applications of Computational Geometry [3-0-0-6] Prerequisites: MA 252 or equivalent

Basics of Computational Geometry - convex hull, line segment intersection, triangulation, linear programming, simplex range searching, voronoi diagram (nearest and farthest), arrangement and duality, visibility; Applications of geometric data structures and algorithms - geographic information system (GIS), robot motion planning, physical design in VLSI.

Texts:

1. M. de Berg, O. Chenong, M. van Kreveld and M. Overmars, Computational Geometry: Algorithms and Application, ,Springer-Verlag, 3rd Edn., 2008.
2. F. Preparata and M. Shamos, Computational Geometry: An Introduction, Springer-Verlag, 1985.

References:

1. K. Mulmuley, Computational Geometry: An Introduction Through Randomized Algorithms, Prentice-Hall, 1994.
2. H. Edelsbrunner, Algorithms in Combinatorial Geometry, Springer-Verlag, 1987.
3. C. J. O'Rourke, Computational Geometry, Cambridge University Press, 1998.

MA 616 Algorithms for Wireless Ad Hoc and Sensor Networks(3-0-0-6) Prerequisites: MA252 / MA512 Data Structures and Algorithms or equivalent

Preamble: Thousands of tiny wireless device, equipped with se nsors, are deployed in some area of interest. After activation the sensors form a self-organized network and provide data. Current research is mainly focused on networ ks that are completely unstructured, but are nevertheless able to communicate, despite the low coverage of their antennas. Such systems are called sensor, adhoc, or mesh networks, depending on the point of view and the application. For a few years now, these networks have been the focus of the research of the networking community. The goal of the course is to elaborate the relevant aspects of the field, from theory to practice.

Syllabus: Introduction and overview of Wireless Sensor Networks, Modeling Sensor and Ad Hoc Networks, Media Access Control, Topology Control, Local Infrastructure: local consensus, local leader election, local reliable broadcast; Clock Synchronization, Localization and Positioning, Coverage, Mobility; Routing : topology-based and position-based, Global Infrastructure: spanning trees, clusters, maximal independent sets, Applications: Data aggregation and maintenance, query-processing, environmental sensing, tracking objects.

Texts/References:

1. D. Wagner and R. Wattenhofer, Algorithms for Sensor and Ad Hoc Networks, Springer, 2007.
2. I. Stojmenovic, Handbook of Sensor Networks: Algorithms and Architectures, Wiley, 2005.
3. F. Zhao and L. Guibas, Wireless Sensor Networks: An Information Processing Approach, Elsevier, 2005.
4. K. Sohraby, D. Minoli and T. Znati, Wireless Sensor Networks: Technology, Protocols, and Applications, Wiley, 2010.
5. J. Schiller, Mobile Communications, 2nd Edn., Pearson, 2006.

MA 621 Rings and Modules (3-0-0-6) Prerequisites: MA 521 (Modern Algebra) or equivalent

Brief review of rings and ideals, nilradical and Jacobson radicals, extension and contraction; basic theory of modules: submodules and quotient modules, module homomorphisms, annihilators, torsion submodules, irreducible modules, Schur's lemma, direct sum and product of modules, free modules, localization, Nakayama's lemma; Exact sequences, short and split exact sequences, projective modules, injective modules, Baer's criterion for injective modules; tensor product of modules, universal property of tensor product, exactness property of tensor products, flat modules; chain conditions on rings, Noetherian rings, Hilbert basis theorem; Artinian rings, discrete valuation rings, Dedekind domains, fractional ideals, ideal class groups.

Texts/References:

1. M.F. Atiyah and I.G. MacDonald, Introduction to Commutative Algebra, Addison Wesley, 1969.
2. D.S. Dummit and R.M. Foote, Abstract Algebra, John Wiley & Sons, Inc., II Edition, 1999.
3. S. Lang, Algebra, III edition, Springer, 2004.
4. P A. Grillet, Abstract Algebra, II edition, Springer 2006
5. T .W. Hungerford, Algebra, Springer, 1996

MA 622 Galois Theory (3-0-0-6) Prerequisites: MA521 (Modern Algebra) or equivalent

Field extensions, algebraic extensions, minimal polynomials, separable and normal extensions; Automorphism groups, fixed fields, Galois extensions, Galois groups; Fundamental theorem of Galois theory, Galois closure; Galois groups of finite fields; Cyclotomic extensions, abelian extensions over rationals, Kronecker-Weber theorem; Galois groups of polynomials, symmetric functions, discriminant, Galois groups of quadratic, cubic and quartic polynomials; solvable extensions, radical extensions, solution of polynomial equations in radicals, insolvability of the quintic; cyclic extensions, Kummer theory, Artin-Schreier extensions; Galois groups over rationals, transcendental extensions, infinite Galois groups.

Texts/References:

1. D.S. Dummit and R.M. Foote, Abstract Algebra, John Wiley & Sons, Inc., II Edition, 1999.
2. I. Stewart, Galois Theory, Academic Press, 1989.
3. J.P. Escofier, Galois Theory, Springer, 2001.
4. Emil Artin, Galois Theory, University of Notre Dame Press,1971

MA 623 Introduction to Algebraic Geometry (3-0-0-6) Prerequisites: MA521 (Modern Algebra) or equivalent

Filtrations, graded rings, graded modules; Krull dimension, depth, going up and going down, primary ideals, prime avoidance theorem, primary decomposition; Hilbert functions, regular local rings, Cohen-Macaulay rings; Zariski topology, Hilbert Nullstellensatz, spectrum of a ring, affine algebraic sets, affine variety, projective variety; Noether normalization, integral closure; algebraic curves, function field of a curve, divisors, principal divisors, Picard group, divisor class group, genus; monomial orderings, division algorithm, Groebner basis, syzygies.

Texts/References:

1. M. F. Atiyah & I. Macdonald, Commutative Algebra, Addison-Wesley, 1969
2. I. Shafarevich, Basic Algebraic Geometry, Springer, 1972
3. D. Eisenbud, Commutative Algebra, Springer, 1995

4. 4.R. Hartshone, Algebraic Geometry, Springer, 1997
5. J. Harris, Algebraic Geometry: A First Course, Springer, 1995
6. E. Kunz, Introduction To Commutative Algebra And Algebraic Geometry, Birkhauser, 1984

MA624 Introduction to Lie Algebras [3-0-0-6] Prerequisites: MA 521 and MA 522 or equivalent.

Lie algebras and Lie algebra homomorphisms (definition and examples), solvable and nilpotent Lie algebras, Engel's theorem; Semisimple Lie algebras - Lie's theorem, Cartan's criterion, Jordan-Chevalley decomposition, killing form, complete reducibility of representations, Weyl's theorem, irreducible representations of the Lie algebra SL(2), weights and maximal vectors, root space decomposition; Root systems - definition and examples, simple roots and the Weyl group, Cartan matrix of a root system, Dynkin diagrams, classification theorem.

Texts/References:

1. J. E. Humphreys, Introduction to Lie Algebras and Representation theory, Graduate texts in Mathematics, Springer, 1972.
2. W. Fulton and J. Harris, Representation theory - A First Course, Graduate texts in Mathematics, Springer, 1991.
3. K. Erdmann and M. J. Wildon, Introduction to Lie Algebras,Springer Undergraduate Mathematics Series, 2006.
4. B.. C. Hall, Lie Groups, Lie Algebras, and Representations, An Elementary Introduction, Graduate Texts in Mathematics, Springer, 2010.
5. N. Jacobson, Lie Algebras, Courier Dover Publications, 1979.

MA626 Representation Theory of Finite and Compact Groups [3-0-0-6] Prerequisites: MA 224 or MA 541 or equivalent

Representations of finite groups, sub-representations, characters of a representation, irreducible representations and Schur's lemma. Topological group, Haar measures, existence theorem for Haar measure on a locally compact group, left and right regular representations, Induced representations. Representations of compact groups, unitary irreducible representations, Peter-Weyl theorems, representations of SO(2), SU(2) etc., Fourier series on the unit sphere S^(n-1).

Texts/References:

1. J. P. Serre, Linear Representations of Finite groups, Springer-Verlag, 1977.
2. Barry Simon, Representation of Finite and Compact Groups, AMS, 1996.
3. G. B. Folland, A course in abstract Harmonic analysis, CRC Press, Boca Raton, 1995

MA627 Modular Forms [3-0-0-6] Prerequisites: MA521 or equivalent, and MA547 or equivalent

Preamble / Objectives (Optional): The aim of this course is to familiarize students with basic concepts, techniques, and applications of modular forms as well as with some modern results about modular forms and their applications.

Course Content/ Syllabus: Modular group, congruence subgroups, fundamental domains, extended upper half-plane; modular forms of level one, examples, Eisenstein series, some number theoretic applications, valence formula, dimension formula; Hecke operators of level one, Ramanujan's tau function; modular forms of higher level, examples, Hecke operators of higher level, Atkin-Lehner theory, Petersson inner product, newforms, Eigenforms, L-functions and some properties, relation between modular forms and elliptic curves.

Texts:

1. M. Ram Murty, M. Dewar, and H. Graves, Problems in the Theory of Modular Forms, Hindustan Book Agency, 2015.
2. F. Diamond and J. Shurman, A First Course in Modular Forms, GTM, vol. 228, Springer, 2005.

References:

1. N. Koblitz, Introduction to Elliptic Curves and Modular Forms, GTM, vol. 97, Springer, 1993.

2. J. P. Serre, A Course in Arithmetic, GTM, vol. 7, Springer, 1973.

MA640 Topology and Calculus of Surfaces [3-0-0-6] Pre-requisites: MA 541 or equivalent

Combinatorial surface, classical Euler characteristic, Barycentric subdivision; Topological surfaces, Rado's theorem on the triangulability of compact surfaces, classification theorem of compact, connected surfaces; Simplicial homology, Betti numbers, Poincare's theorem on Euler characteristic; Differential surfaces, tangent spaces, vector fields, Poincare index theorem; Topological and differential manifolds.

Texts/References:

1. L.C. Kinsey, Topology of Surfaces, Springer, 1993.
2. M.A. Armstrong, Basic Topology, Springer, 2010.
3. M. Henle, A Combinatorial Introduction To Topology, Dover, 1994.

MA641 Operator Theory in Hilbert Spaces [3-0-0-6] Prerequisites: MA543 or equivalent

Review of Hilbert spaces, orthonormal bases, weak convergence; Bounded operators on Hilbert spaces, adjoints of bounded operators, algebra of bounded operators; Orthogonal projections, isometric and unitary operators, finite rank and compact operators, Hilbert-Schmidt operators, selfadjoint and normal operators; Spectra of bounded operators, invariant and reducing subspaces; Spectral theorem for compact operators, polar and singular value decompositions, Schatten class operators; Spectral theorem for bounded selfadjoint and normal operators.

Texts/References:

1. J. B. Conway, A course in Functional Analysis, 2nd Edn., Springer-Verlag, 1990.
2. J. Weidmann, Linear Operators in Hilbert Spaces, Springer-Verlag, 1980.
3. G. Helmberg, Introduction to Spectral Theory in Hilbert Space, North-Holland, 1975.
4. B. V. Limaye, Functional Analysis, 2nd edition, New Age International, New Delhi, 1996.

MA 643 Algebraic Topology(4-0-0-8) Prerequisites: MA549 Topology or equivalent

Preamble: This course introduces the basic concepts and tools from algebraic topology and provides an important viewpoint for anyone who wishes to pursue further study in the field of geometry and topology.

Syllabus: Homotopy of paths, fundamental group of a space, homomorphism between fundamental groups induced by a map between spaces, homotopy equivalence and homotopy type, the Seifert-van Kampen's theorem and its applications. Covering spaces: Definition and examples, lifting of paths, fundamental group of a covering space, lifting of maps, deck transformations and group actions, regular covering spaces and quotient spaces. Homology: Simplicial homology, singular homology, invariance of homology groups under homotopy, excision, degree of a map from S^n to itself, cellular homology, Mayer-Vietoris sequen ces, homology with co-efficients.

Texts/References:

1. W. S. Massey, A Basic Course in Algebraic Topology, Springer, 1991.
2. A. Hatcher, Algebraic Topology, Cambridge, 2002.
3. J. R. Munkres, Elements of Algebraic Topology, Perseus Publishing, 1984.

MA 644 Differential Topology(4-0-0-8) Prerequisites: MA549 Topology or equivalent

Preamble: This course is an introduction to the modern methods of studying calculus on manifolds. It covers topics like the derivative of a function between manifolds, performing integration on a manifold, Stokes' Theor em as a generalization of the Fundamental Theorem of Calculus and ends with the remarkable theorem of de Rham - which establishes an intricate link between objects on a manifold derived from the disparate sources of topology and calculus.

Syllabus: Differential manifolds, Smooth maps, Tangent spaces, Tangent bundle, Differential of a smooth map. Submersions, Immersions, Embeddings, Submanifolds and Sard's Theorem. Cotangent Bundle, Tensors, Differential forms, Exterior derivative, Closed and exact forms, Poincare Lemma. Orientation on manifolds, Integration, Stokes' Theorem, de Rham cohomology and the theorem of de Rham.

Texts/References:

1. V. Guillemin and A. Pollack, Differential Topology, American Mathematical Society, Reprint Edition, 2010
2. J. M. Lee, Introduction to Smooth Manifolds, Springer, 2002.
3. M. Spivak, A Comprehensive Introduction to Differential Geometry, Vol.1, Publish or Perish, 3rd Edn., 1999

MA 645 Introduction to C*- Algebras(3-0-0-6) Prerequisites: MA543 or equivalent

Banach algebra, basic properties of spectra, Ideals and homomorphisms, Gelfand transforms, Involutions, C^*-Algebra, Gelfand-Naimark theorem for commutative C^*- Algebras, positive linear functionals and the Gelfand-Naimark-Segal construction.

Texts/References:

1. R.V. Kadison and J.R. Ringrose, Fundamentals of the theory of operator algebras. Vol. I. Elementary theory, GSM, 15. AMS, Providence, RI, 1997.
2. G.J. Murphy, C.-algebras and operator theory, Academic Press, Inc., Boston, MA, 1990.
3. R.G. Douglas, Banach algebra techniques in operator theory, 2nd Edn. GTM, 179. Springer-Verlag, New York, 1998.

MA 646 Advanced Operator Theory (3-0-0-6) Prerequisites: MA543 or equivalent

Review of spectral theory of bounded self-adjoint and normal operators, resolution of identity; unbounded operators: basic properties and examples, symmetric and self-adjoint operators, Cayley transform, unbounded normal operators and the spectral theorem, symbolic calculus.

Texts/References:

1. J.B. Conway, A course in operator theory, GSM, 21. AMS, Providence, RI, 2000.
2. W. Rudin, Functional Analysis, Tata Mc. Graw Hill, 1974.
3. K. Schmudgen, Unbounded self-adjoint operators on Hilbert space, GTM, 265. Springer, 2012..

MA 647 Riemann Surfaces (3-0-0-6) Prerequisites: MA 547 (Complex Analysis)

Course Content/ Syllabus: Riemann surfaces: definitions, examples, basic properties, degree and genus; Analytic continuation: Riemann surface of an analytic germ; Differential forms on Riemann surfaces: Weyl's lemma and the Hodge decomposition, Examples of meromorphic functions and differentials; Homology bases and holomorphic differentials, Periods and bilinear relations, Divisors, Riemann-Roch and the theorems of Abel and Jacobi; Uniformization

References:

1. Wilhelm Schlag, A course in Complex Analysis and Riemann Surfaces, Graduate Studies in Mathematics: Volume 154, American Mathematical Society, 2014.
2. Simon Donaldson, Riemann surfaces, Oxford Graduate Texts in Mathematics, Vol. 22, Oxford University Press, Oxford, 2011.
3. Rick Miranda, Algebraic Curves and Riemann Surfaces, Graduate Studies in Mathematics, Series No. 5, American Mathematical Society, 1995.
4. Dr. Heinrich Durè, Elements of the theory of functions of a complex variable with especial reference to the methods of Riemann, Authorized translation from the 4th German Edition (1893) by George Egbert Fisher and Isaac J. Schwatt, Norwood Press, 1896.

MA 649 Harmonic Analysis on Euclidian Spaces (3-0-0-6) Prerequisites: MA 550 Measure Theory or MA224 Real Analysis

Course Content/ Syllabus Distribution function, decreasing rearrangements weak Lp spaces and Lorentz Spaces, Marcinkiewicz Interpolation Theorem, Riesz–Thorin Interpolation Theorem and Interpolation of Analytic Families of Operators, Off-Diagonal Marcinkiewicz Interpolation Theorem, Hardy–Littlewood Maximal Operator and Lebesgue differentiation Theorem, Class of Schwartz Functions, Class of Tempered Distributions and their Fourier transform; Convolution Operators on Lp Spaces and Multipliers, Hilbert Transform and Riesz Transforms, Homogeneous Singular and Maximal Singular Integrals, Calderon–Zygmund Decomposition and Singular Integrals.

Texts:

1. Javier Duoandikoetxea, Fourier Analysis, GSM Vol 29 AMS 2000
2. Loukas Grafakos, Classical Fourier Analysis, 2nd Edition, Springer 2000

References:

1. Elias M Stein, Harmonic Analysis, Princeton University Press 1993
2. Elias M Stein and Rami Shakarchi, Functional Analysis, Princeton University Press 2011

MA 648 Operator Theory on Hardy Spaces (3-0-0-6) Prerequisites: MA543 or equivalent

Course Content/ Syllabus: Review of l^2 and L^2 -spaces, Hardy spaces: H^1, H^2 and H^∞; kernel function, reproducing kernel Hilbert spaces, examples of reproducing kernel Hilbert spaces different from Hardy spaces; shift operators (unilateral and bilateral) on the Hardy spaces, spectrum of shift operators; isometries, Wold-decomposition theorem; inner-outer functions, the inner-outer factorization of functions in H^2 , Beurling's theorem, The F. Riesz and M. Riesz theorem; Toeplitz matrices, basic properties of Toeplitz operators; introduction to vector-valued Hardy spaces.

Texts:

1. P. R. Halmos, A Hilbert Space Problem Book, Graduate Texts in Mathematics, New-York: Springer Verlag, 1982.
2. J. B. Conway, A course in Operator Theory, Graduate Texts in Mathematics, Volume 21, American Mathematical Society, Providence, RI, 2000.

References:

1. R. A. Martinez-Avendano and P. Rosenthal, An introduction to operators on the Hardy-Hilbert space, Graduate Texts in Mathematics, Springer, New-York, 2007.
2. H. Radjavi and P. Rosenthal, Invariant Subspaces, Second Edition, Springer-Verlag, New-York,1973.
3. R. G. Douglas, Banach Algebra Techniques in Operator Theory, Second Edition, Graduate Texts in Mathematics, Volume 179, Springer-Verlag, New-York, 1998.

MA 651 Distributed Algorithms (3-0-0-6) Prerequisites: MA512/MA252 or equivalent

Overview of distributed computing, basics of distributed networks algorithms, Time in distributed system, distributed mutual exclusion, distributed snapshot and global state collection, graph algorithms, coordination algorithms, fault and fault-tolerance, distributed consensus and agreement algorithms, distributed transactions, group communication, replicated data management, self-stabilization, applications in wireless sensor networks

Texts:

1. S. Ghosh, Distributed Systems: An Algorithmic Approach, 2nd Edition (Indian Reprint), CRC Press, 2015.
2. D. Peleg, Distributed Computing: A Locality-Sensitive Approach, SIAM, 2000
3. Nancy Lynch, Distributed Algorithms, Morgan Kaufmann, 1996.

References:

1. M. V. Steen, A. Tanenbaum: Distributed Systems, 3rd Edition, Pearson 2017.
2. H. Attiya and J. Welch. Distributed Computing: Fundamentals, Simulations, and Advanced Topics, Second Edition, Wiley, 2006.
3. G. Tel, Introduction to Distributed Algorithms, Cambridge University Press 2000
4. A. Kshemkalyani, M. Singhal, Distributed Computing: Principles, Algorithms, and Systems, Cambridge University Press, 2007.
5. V. K. Garg, Elements of Distributed Computing, Wiley & Sons, 2002.

MA 652 Approximation Algorithms (3-0-0-6) Prerequisites: MA 512 Data Structures & Algorithms or MA 252 Design and Analysis of Algorithms or equivalent

Course Content/ Syllabus: Vertex cover, Dominating set, Independent set, Dispersion set, Set cover, max-SAT, knapsack, bin packing, scheduling, spanners, Steiner trees, cuts, clustering, facility location, traveling salesman tour; greedy, local search, dynamic programming, linear program formulations, dual fitting, primal-dual method, rounding of linear programs, random sampling, derandomization, power of two solutions. Lower bounds on approximations and the relevant complexity classes.

Texts:

1. David P. Williamson and David B. Shmoys, The Design of Approximation Algorithms, First Edition, Cambridge University Press, 2011.
2. Vijay V. Vazirani, Approximation Algorithms, First Edition, Springer, 2004

References:

1. Sariel Har-Peled, Geometric Approximation Algorithms, American Mathematical Society, 2011
2. Giorgio Ausiello, Pierluigi Crescenzi, Giorgio Gambosi, Viggo Kann, Alberto Marchetti Spaccamela and Marco Protasi, Complexity and Approximation: Combinatorial Optimization Problems and Their Approximability Properties, First Edition, Springer-Verlag, 1999.
3. Giri Narasimhan and Michiel Smid, Geometric Spanner Networks, First Edition, Cambridge University Press, 2007

MA 661 Integral Transforms and Integral Equations (3-0-0-6) Prerequisites: MA542 Differential Equations or its equivalent

Preamble: This course aims at providing basic ideas of integral transforms and integral equations and how they can be utilized to solve initial/boundary value problems. Many problems, not easily solvable by standard methods, can be appropriately handled by means of integral transforms and integral equations. This course will benefit interested senior undergraduate, Master's and Doctoral students of a number of departments.

Syllabus: Basic integral transforms: Fourier transform, Fourier sine and cosine transforms, Laplace transform, Hankel transform, Mellin transform, Radon transform. Finite Fourier sine and cosine transforms, finite Hankel transforms. Construction of the kernels of integral transforms: kernels on a finite interval, circular region, a semi-finite interval and radially symmetric interval, kernels for discrete to continuous spectrum. Applications to ODEs, hyperbolic PDEs.

Occurrence of integral equations, Regular integral equations: Volterra integral equations, Fredholm integral equations, Volterra and Fredholm equations with regular kernels. Symmetric kernels and orthogonal systems of functions. Singular integral equations: weakly singular integral equations, Cauchy singular integral equations, hypersingular integral equations. Bernstein polynomials: properties and its use in solving integral equations. Green's function in integral equations.

Texts/References:

1. L. Debnath and D.D. Bhatta, Integral Transforms and Their Applications, Book World Enterprises, 2006.
2. M. Ya. Antimirov, A.A. Kolyshkin, R. Valliancourt, Applied Integral Transforms, CRM Monograph Series, American Mathematical Society, 2007.
3. A.D Poularikas, The Transforms and Applications Handbook, CRC Press, 1996.
4. F.G Tricomi, Integral Equations, Dover Publications Inc. New York, 1985.
5. D. Porter and D.S.G. Stirling, Integral Equations: A Practical Treatment from Spectral Theory to Applications, Cambridge University Press, 1990.
6. N.I. Muskhelishvili, Singular Integral Equations, Dover Publications Inc., New York, 2008.

MA663 Fractional Calculus and Fractional Differential Equations [3-0-0-6] Prerequisites: MA542 or equivalent

Preamble
In a number of practical problems, integral-order derivatives and differential equations do not convey the exact picture of the situation. The use of the concept of fractional calculus shows new ways to tackle these problems.

This course is aimed at introducing the methods and tools of fractional order calculus to science and engineering students of B.Tech, M.Sc., M.Tech. and Ph.D. students.

Outline
Special functions of fractional calculus: Gamma function, MIttag-Leffler function, Wright function. Fractional derivatives and integrals: Grunwald-Letnikov fractional derivatives, Riemann-Liouville fractional derivatives, geometric and physical interpretation of fractional integration and differentiation, sequential fractional derivatives, properties of fractional derivatives, Laplace, Fourier and Mellin transforms of fractional derivatives. Linear fractional differential equations: Equation of a general form, existence and uniqueness theorem as a method of solution, dependence of a solution on initial conditions, Laplace transform method, standard fractional differential equations, sequential fractional differential equations. Some methods for solving fractional order equations: Mellin transform, power series, orthogonal polynomials, numerical evaluation of fractional derivatives, approximation of fractional derivatives. Texts/References:

1. Basic Theory of Fractional Differential Equations, Y. Zhou, World Scientific, 2014.
2. Fractional Differential Equations, I. Podlubny, Academic Press, 1998.
3. The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order, K.B. Oldham and J. Spanier, Dover Publications, 2006.
4. An Introduction to the Fractional Calculus and Fractional Differential Equations, K.S. Miller and B. Ross, Wiley-Interscience, 1993.

MA664 Theory and Applications of Sobolev Spaces [3-0-0-6] Prerequisites: MA543 or equivalent

Theory of Sobolev spaces: Motivation, weak derivative, definition and basic properties of Sobolev spaces, extension theorem, embedding and compactness theorems, Dual spaces, fractional order Sobolev spaces, Trace theory. Methods for solving Elliptic boundary value problems: Weak solution of elliptic boundary value problem, regularity of weak solutions, maximum principle, eigenvalue problems. Solving elliptic boundary value problem using fixed point method, Galerkin method, monotone iteration method and variational method.

Texts/References:

1. R. A. Adams and J.J.F. Fournier, Sobolev Spaces, Academic Press, 2003.
2. H. Brezis, Functional Analysis, Sobolev Spaces and Partial Differential Equations, Springer, 2011.
3. S. Kesavan, Topics in Functional Analysis and Applications, New Age International Private Limited, 2015.

MA665 Stochastic Models in Biology [3-0-0-6] Prerequisites: MA 225 or equivalent and MA 590 or equivalent

Course Content/ Syllabus: Review of probability theory and stochastic processes; Discrete-time Markov chains, classification of states, first passage time, stationary probability distribution, finite Markov chains, Monte Carlo simulation, biological applications of discrete-time Markov chains; Discrete-time branching processes; Continuous-time Markov chains, generator matrix, embedded Markov chains, classification of states, Kolmogorov differential equations, stationary probability distribution, finite Markov chains, generating function techniques, biological applications of continuous-time birth, death and Markov chains; Diffusion process, stochastic differential equations, biological applications of stochastic differential equations.

Texts:

1. Linda J.S. Allen, An Introduction to Stochastic Processes with Applications to Biology, Second Edition, CRC Press, 2011.

References:

1. James D. Murray, Mathematical Biology I: An Introduction, Interdisciplinary Applied Mathematics, Third Edition, Springer, 2007.

MA667 Actuarial Mathematics [3-0-0-6] Prerequisites: MA 590 Probability Theory or MA 225 Probability Theory and Random Processes or equivalent

Course Content/ Syllabus: Basics of time value of money, Interest rates, Annuities; Mortality theory, Survival time, Actuarial functions of mortality, Mortality tables; Life insurance and annuities, Cash flows, Endowments, Life annuities; Premiums, Net and Gross premiums.

Texts:

1. Arjun K. Gupta and Tamas Varga, An Introduction to Actuarial Mathematics, Vol. 14. Springer Science & Business Media, 2013.

References:

1. S. David Promislow, Fundamentals of Actuarial Mathematics, Wiley, 2015.

MA671 Finite Element Methods for Partial Differential Equations [3-0-0-6] Prerequisites: MA322/MA572 or equivalent

Basic concepts of finite element methods; Elements of function spaces, Lax-Milgram theorem, piecewise polynomial approximation in function spaces, Galerkin orthogonality and Cea s lemma, Bramble-Hilbert lemma, Aubin-Nitsche duality argument; Applications to elliptic, parabolic and hyperbolic equations, a priori error estimates, variational crimes; A posteriori error analysis reliability, efficiency and adaptivity.

Texts/References:

1. C. Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method, Dover Publications, 2009.
2. P. G. Ciarlet, The Finite Element Method for Elliptic Problems, North-Holland, 1978.
3. J. N. Reddy, An Introduction to Finite Element Method, McGraw Hill, 1993.
4. S. C. Brenner and L. R. Scott, The Mathematical Theory of Finite Element Methods, 2nd edition, Springer, 2002.
5. Z. Chen, Finite Element Methods and Their Applications, Springer, 2005.
6. D. L. Logan, A First Course in the Finite Element Method, 4th edition, Cenegage Learning India Pvt Ltd, 2007.
7. A. J. Davies, The Finite Element Method: An Introduction with Partial Differential Equations, Oxford University Press, 2011.

MA681 Applied Stochastic Processes [3-0-0-6] Prerequisites: MA225/MA590 or equivalent

Review of probability theory; Discrete-time Markov chains, renewal and regenerative processes, Poisson processes, continuous-time Markov chains, martingales, Brownian motion; Application to queues, communications, finance, biology and manufacturing.

Texts/References:

1. R. Serfozo, Basics of Applied Stochastic Processes, Springer, 2009.
2. M. Lefebvre, Applied Stochastic Processes, Springer, 2007.
3. R. F. Bass, Stochastic Processes, Cambridge University Press, 2011.
4. S. Resnick, Adventures in Stochastic Processes, Birkhauser, 1992.
5. A. Goswami and B.V. Rao, A Course in Applied Stochastic Processes, Hindustan Book Agency, 2006.
6. U. N. Bhat and G. K. Miller, Elements of Applied Stochastic Processes, 3rd edition, Wiley, 2002.
7. H. J. Tijms, A First Course in Stochastic Models, Wiley, 2003.
8. G. R. Grimmett and D. R. Stirzaker, Probability and Random Processes, 3rd edition, Oxford University Press, 2001.
9. S. M. Ross, Stochastic Processes, 2nd edition, Wiley, 1995.

MA682 Statistical Inference [3-0-0-6] Prerequisites: MA225/MA590 or equivalent

Review of probability theory; Sampling distributions; Point estimation - estimators, sufficiency, completeness, minimum variance unbiased estimation, maximum likelihood estimation, method of moments, Cramer-Rao inequality, consistency; Interval estimation; Testing of hypotheses - tests and critical regions, Neymann-Pearson lemma, uniformly most powerful tests, likelihood ratio tests; Basic non-parametric tests.

Texts/References:

1. G. Casella and R. L. Berger, Statistical Inference, 2nd edition, Duxbury Press, 2001.
2. J. Shao, Mathematical Statistics, 2nd edition, Springer, 2007.
3. V. K. Rohatgi and A. K. Md. E. Saleh, An Introduction to Probability and Statistics, 2nd edition, Wiley, 2000.
4. B. L. S. Prakasa Rao, A First Course in Probability and Statistics, World Scientific/Cambridge University Press India, 2009.
5. G. G. Roussas, An Introduction to Probability and Statistical Inference, Academic Press, 2002.
6. K. L. Chung, A Course in Probability Theory, 3rd edition, Elsevier, 2001.

MA684 Advanced Probability [3-0-0-6] Prerequisites: MA590 or equivalent

Measure theoretic formulation of probability; Random variables, Distributions, Expectations, Modes of convergence; Laws of large numbers:the weak and strong laws; Characteristic functions, Convergence in distribution, Central limit theorems; Markov chains, Random walks, Poisson process; Conditional expectations; Discrete parameter martingales,Convergence theorems for martingales; Brownian motion, Strong Markov property, Introduction to sample path properties.

Texts:

1. J.B. Walsh, Knowing the Odds: An Introduction to Probability, American Mathematical Society, 2012.
2. K. B. Athreya and S. N. Lahiri, Probability Theory, TRIM series, 2006.

References:

1. P. Billingsley, Probability and Measure, Wiley India, 3rd Edn., 2008.
2. R. Durrett, Probability: Theory and Examples, Cambridge University Press, 4th Edn.,2010.
3. O. Kallenberg, Foundations of Modern Probability, Springer, 2nd Edn., 2002.

MA685 Martingales and Brownian Motion [3-0-0-6] Prerequisites: MA590 or equivalent

Review of measure theoretic formulation of probability; Conditional expectations, Martingales, Convergence, Uniform integrability, Applications; Brownian motion, Construction of Brownian motion, Stopping times and Strong Markov property, Zero set of Brownian motion, Reflection principle, Recurrence and hitting properties, Path irregularity, Skorokhod embedding, Glimpses of a few advanced topics: processes derived from Brownian motion and the Wiener integral.

Text:

1. J. B. Walsh, Knowing the Odds: An Introduction to Probability, American Mathematical Society, 2012.

References:

1. R. Durrett. Probability: Theory and Examples, 4th Edn, Cambridge University Press, 2010.
2. O. Kallenberg, Foundations of Modern Probability, 2nd Edn, Springer, 2002.
3. P. Mörs and Y. Peres, Brownian motion, Cambridge University Press, 2010.
4. D. Williams, Probability with Martingales, Cambridge University Press, 1991.

MA686 Random Graphs [3-0-0-6] Prerequisites: MA225 or MA590

Probabilistic tools for random graphs: Convergence of random variables, probabilistic bounds, coupling, martingales; Branching processes: Survival vs extinction, random walk perspective, binomial and Poisson branching processes; Erdos-Renvi random graphs: Comparison to branching processes, phase transition for the largest connected component, central limit theorem for the giant component, behavior in the critical window, degree structure; Random graph models for complex networks: Degree structure, connectivity properties, small world behavior.

Text:

1. R. V. D. Hofstad, Random Graphs and Complex Networks, Volume 1, Cambridge Series in Statistical and Probabilistic Mathematics, Cambridge University Press, 2017.

2. R. Durrett, Random Graph Dynamics, Cambridge Series in Statistical and Probabilistic Mathematics, Cambridge University Press, 2007.

References:

1. B. Bollobas Random Graphs, Second edition, Cambridge studies in advanced mathematics, Cambridge University Press, 2001

MA687 Generalized Linear Models [3-0-0-6] Prerequisites: MA589 (Statistical Foundations for Data Science) or MA324 (Statistical Inference and Multivariate Analysis) or Equivalent

Preamble / Objectives (Optional): Generalized linear model (GLM) is widely used in both academia and industry. In this course, the student will learn the theory related to GLM as well as when and how to apply GLMs in real data. We will cover GLMs for different types of response variables like continuous, binary, multinomial, and count. Topics will be covered with supporting data analysis in statistical software R.

Course Content/ Syllabus: Review of linear models: simple and multinomial linear regressions. Generalized linear models (GLM): the process of model fitting, components of GLM, measuring the goodness of fit, residual analysis, algorithm to fit GLMs.Models for binary data: logistic regressions, probit, log-log and others. Models for multinomial data: multinomial logit. Models for count data: Poisson, negative binomial and others, analysis of contingency table, analysis of ordinal data.

Text/References:

1. Peter McCullagh and John Nelder, Generalized Linear Models, Second Edition, Chapman and Hall/CRC (1989).
2. Julian J. Faraway, Extending the Linear Model with R: Generalized Linear, Mixed Effects, and Non-parametric Regression Models, Second Edition, Boca Raton: CRC Press (2006).

MA688 Stochastic Calculus [3-0-0-6] Prerequisites: Nil

Preamble / Objectives (Optional): This course aims to provide a mathematical introduction to the theory of stochastic calculus for continuous semi-martingales for students having some knowledge of measure theoretic probability. The main tool of stochastic calculus is Ito's formula and this course includes several important applications of Ito's formula and gives practice with explicit calculations. This course will also provide the necessary theoretical background for applications in other fields.

Course Content/Syllabus: Concepts from probability theory and stochastic processes, filtrations, martingales, Brownian motion. Continuous semi-martingales, existence of quadratic variation of a local martingale. Stochastic integration, construction of stochastic integral with respect to continuous semi-martingale. Ito's formula with applications: Levy's characterization of Brownian motion, continuous martingales as time changed Brownian motion, Burkholder-Davis-Gundy (BDG) inequalities, Girsanov's theorem with applications. Theory of Markov processes, Feller semi-groups.

Text/References:

1. Jean-Francois Le Gall, Browninan Motion, Martingales, and Stochastic Calculus, Graduate Texts in Mathematics 274, Springer, 2016.
2. F.C. Klebaner, Introduction to Stochastic Calculus with Applications, Imperial College Press, Third Edition, 2012.

MA689 Stochastic Integration [3-0-0-6] Prerequisites: MA 372 (Stochastic Calculus for Finance) or Equivalent

Course Content/ Syllabus: Review of Brownian motion and stochastic integration with respect to Brownian motion; extension of stochastic integral for a larger class of integrands, stopping times, local martingales; stochastic integration with respect to right continuous with left limits (RCLL) square integrable martingales, Doob Meyer decomposition; Ito's formula for martingales, local time, Tanaka's formula; multiple Weiner-Ito integrals.

Text:

1. H. H. Kuo, Introduction to Stochastic Integration, Springer, 2006.

References:

1. N. Ikeda and S. Watanabe, Stochastic Differential Equations and Diffusion Processes, Second Edition, Elsevier, 2014.

MA690 Understanding Statistical Learning Theory [3-0-0-6] Prerequisites: MA225 or MA 323 or MA590 or equivalent>

Course Content/ Syllabus: Probabilistic Formulations of Prediction Problems; Linear Threshold Functions and the Perceptron Algorithm; Minimax Risk Bounds for Linear Threshold Functions; Kernel Methods: Support Vector Machines; Review of Constrained Optimization; Soft-margin SVMs, Reproducing kernel Hilbert spaces; Representer theorem; Constructing kernels; Convex loss versus 0-1 loss; logistic regression; softmax regression; Regularization; AdaBoost; AdaBoost and large margin classifiers; AdaBoost; Risk bounds; Concentration inequalities ; Glivenko-Cantelli classes and Rademacher averages; Rademacher averages and Vapnik-Chervonenkis dimension; Sauer's Lemma; Rademacher averages and growth function; Growth function bounds for parameterized binary classes; Covering numbers; Model selection; Online learning: Halving algorithm. Exponential weights; Online convex optimization: gradient descent; Online convex optimization: mirror descent; Online convex optimization: ridge regression, lasso, elastic net, k-nearest neighbour, adaptivity; Convex optimization in a combined regression (Cobra), XGBoost and Adaboost set up; Formulation of Neural network, recommendation systems as Non-convex optimization with specific theoretical analysis ; Follow the perturbed leader, online shortest path; Online bandit problems; Universal portfolios; Online to batch conversions.

Texts:

1. Shar Shalev-Shwartz and Shar Ben-David, Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press, 2014.

References:

1. Vladimir N. Vapnik, The Nature of Statistical Learning Theory, Springer, 2013.
2. Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
3. Trevor Hastie, Robert Tibshirani, and Jerome Friedman, The Elements of Statistical Learning, Springer Series in Statistics, 2009.

MA691 Advanced Statistical Algorithms[3-0-0-6] Prerequisites: MA225 Probability Theory and Random Process or MA 323 or equivalent

Course Content/ Syllabus: Introduction to probability distributions. Basics of estimation and testing of hypothesis(frequentist approach, bayesian approach). Discrete and continuous multivariate distributions (multinomial, multivariate normal etc); Different Censoring algorithms and its application (Type-I , Type-II, hybrid, progressive.); Advanced EM algorithm (higher dimensional estimation); Bayesian filters (Kalman Filter, Extended Kalman, Particle Filter and their applications). Advanced Monte Carlo Techniques: Importance sampling, Monte Carlo Markov Chain and its variations (EM MCMC, Slice sampling, Hamiltonian Monte Carlo etc). Basics of Hidden Markov Model (forward backward algorithm, Viterbi algorithm, Baum-welch algorithm). Deep learning techniques (Back propagation, autoencoder, restricted Boltzmann machine etc); Genetic Algorithm: single objective GA, multi - objective NSGA.

Texts:

1. K. P. Murphy, Machine Learning – A Probabilistic Perspective, MIT Press, 2012.
2. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006
3. D. Kundu, Statistical Computing: existing methods and recent development, Alpha Science International, 2004.

References:

1. J.E. Gentle, Elements of computational Statistics, Springer Series in Statistics and computing,2002
2. T. Say, Analysis of Financial Time Series, Wiley Series in Probability and Statistics, 2nd Edn., 2005

3. W. Zucchini and I. L. MacDonald, Hidden Markov Model for time series: an introduction using R, 2nd Edn., CRC Press, 2016.
4. J.E. Gentle, Elements of computational Statistics, Springer Series in Statistics and computing, 2002.

Last updated: 11 February 2021