Semester-wise Pattern for Students Admitted to M.Sc. Mathematics Programme									
Year	**First Semester**			**U**	**Second Semester**			**U**
I	BIO	F110	Biology Laboratory	1	MATH	F112	Mathematics II	3
	BIO	F111	General Biology	3	ME	F112	Workshop Practice	2
	CHEM	F110	Chemistry Laboratory	1	CS	F111	Computer Programming	4
	CHEM	F111	General Chemistry	3	EEE	F111	Electrical Sciences	3
	MATH	F111	Mathematics I	3	BITS	F112	Technical Report Writing	2
	PHY	F110	Physics Laboratory	1	MATH	F113	Probability and Statistics	3
	PHY	F111	Mechanics, Oscillations and Waves	3	BITS	F111	Thermodynamics	3
	BITS	F110	Engineering Graphics	2				
				17				**20**
II	MATH	F211	Mathematics III	3	ECON	F211	Principles of Economics	3
			Humanities Electives	3(min)			or	or
	MATH	F212	Optimization	3	MGTS	F211	Principles of Management	3
	MATH	F213	Discrete Mathematics	3			Humanities Electives	3(min)
	MATH	F214	Elementary Real Analysis	3	MATH	F241	Mathematical Methods	3
	MATH	F215	Algebra I	3	MATH	F242	Operations Research	3
	BITS	F225	Environmental Studies	3	MATH	F243	Graphs & Networks	3
					MATH	F244	Measure & Integration	3
				21(min)				**18(min)**
Summer	**BITS F221 Practice School – I (for PS Option Only)**							
III			Open/Humanities Electives	3 to 6			Open/Humanities Electives	0 to 3
	MATH	F311	Introduction to Topology	3	MATH	F341	Introduction to Functional Analysis	3
	MATH	F312	Ordinary Differential Equations	3	MATH	F342	Differential Geometry	3
	MATH	F313	Numerical Analysis	3	MATH	F343	Partial Differential Equations	3
			Discipline Electives	6			Discipline Electives	9
				18/21				**18/21**
IV			Open Electives	8 to14	BITS	F412	Practice School-II	20
							or	or
					BITS	F421T	Thesis	16
							or	
							Thesis (9) and Electives (6 to 9)	15 to18
				8/14				**15/20**

DISCIPLINE ELECTIVE COURSES		**L**	**P**	**U**
BITS F314	Game Theory and Its Applications	3	0	3
BITS F316	Nonlinear Dynamics and Chaos	3	0	3
BITS F343	Fuzzy Logic and Applications	3	0	3
BITS F386	Quantum Information and Computing	3	0	3
BITS F463	Cryptography	3	0	3
CS F211 **or** BITS F232	Data Structures and Algorithms **or** Foundations of Data Structures and Algorithms	3 3	1 1	4 4
CS F364	Design and Analysis of Algorithms	3	0	3
MATH F231	Number Theory	3	0	3
MATH F314	Algebra II	3	0	3
MATH F315	Introduction to Statistical Inference	3	0	3
MATH F316	Matrix Theory and Linear Estimation	3	1	4
MATH F317	Sampling Theory	3	1	4
MATH F353	Statistical Inference and Applications	3	0	3
MATH F354	Complex Analysis	3	0	3
MATH F378	Advanced Probability Theory	3	0	3
MATH F420	Mathematical Modeling	3	0	4
MATH F421	Combinatorial Mathematics	3	0	3
MATH F422	Numerical Methodology for Partial Differential Equations	3	1	4
MATH F423	Introduction to Algebraic Topology	3	0	3
MATH F424	Applied Stochastic Process	3	1	4
MATH F425	Numerical Linear Algebra	3	1	4
MATH F426	Mathematical Theory of Finite Element Methods	3	1	4
MATH F427	Statistical Simulation and Data Analysis	3	1	4
MATH F428	Time Series Analysis and Forecasting	3	1	4
MATH F431	Distribution Theory	3	0	3
MATH F432	Applied Statistical Methods	3	0	3
MATH F441	Discrete Mathematical Structures	3	0	3
MATH F444	Numerical Solutions of Ordinary Differential Equations	3	0	3
MATH F445	Mathematical Fluid Dynamics	3	0	3
MATH F456	Cosmology	3	0	3
MATH F471	Nonlinear Optimization	3	0	3
MATH F481	Commutative Algebra	3	0	3
MATH F492	Wavelet analysis and applications	3	1	4
MAC F211	Linear Algebra and Its Applications	3	0	3
MAC F244	Stochastic Calculus and Application to Finance	3	0	3
MAC F313	Statistical Data Analysis	3	1	4
MAC F411	Computation of Option Pricing Models	3	1	4

M.Sc. Mathematics

MATH F111 Mathematics I **3 0 3**

Functions and graphs; limit and continuity; applications of derivative and integral. Conics; polar coordinates; convergence of sequences and series. Maclaurin and Taylor series. Partial derivatives. Vector calculus in R^n; vector analysis; theorems of Green, Gauss and Stokes.

MATH F112 Mathematics II **3 0 3**

Complex numbers, analytic functions, Cauchy's theorems; elementary functions; series expansions; calculus of residues and applications. Vector space; basis and dimension; linear transformation; range and kernel of a linear transformation; row reduction method and its application to linear system of equations.

MATH F113 Probability & Statistics **3 0 3**

Probability spaces; conditional probability and independence; random variables and probability distributions; marginal and conditional distributions; independent random variables; mathematical expectation; mean and variance; binomial, Poisson and normal distributions; sum of independent random variables; law of large numbers; central limit theorem (without proof);sampling distribution and test for mean using normal and student's t-distribution; test of hypothesis; correlation and linear regression.

MATH F114 Mathematics for Business **3 0 3**

Ratios and Proportions, Simple and Compound interest, Percentage, Bill Discounting, Mathematical reasoning with basic application, Algebra, Set Theory and application of Venn Diagram, Variation, Indices, Logarithms, Permutation and Combinations, Simultaneous Equation models with business applications, Quadratic Equations and applications, Determinants and Matrices, Calculus with Business applications, Constant and variables, Functions, Limit and Continuity, Differentiation, Partial Differentiation and business applications, Derivatives, Maxima and Minima in the context of business studies, Indefinite Integrals, Definite Integrals, Index Numbers

MATH F211 Mathematics III **3 0 3**

Eigen-values and eigen-vectors. Inner product space and orthonormal bases. Elementary differential equations, Hypergeometric equations, Lengendre polynomials, Bessel functions; Fourier series; Sturm-Liouville problem, series solution for differential equation, systems of first order equations; Laplace transformation and application to differential equations; one dimensional wave equation, one dimensional heat equation & Laplace equation in rectangular form.

MATH F212 Optimization **3 0 3**

Introduction to optimization; linear programming; simplex methods; duality and sensitivity analysis; transportation model and its variants; integer linear programming nonlinear programming; multi-objective optimization; evolutionary computation techniques.

MATH F213 Discrete Mathematics **3 0 3**

Set theory: Sets, relations and functions, equivalence relations, partially ordered sets, countability of sets, lattices and Boolean algebras; Logic and Methods of Proof: Propositional logic, language of propositional logic, predicate logic and logical inference with quantifiers, introduction to different standard proof techniques; Combinatorics: Counting techniques: pigeon hole principle, inclusion-exclusion principle, recurrence relation, and generating function, partitions, special numbers like Fibonacci, Stirling, and Catalan numbers (Just an introduction). Graph Theory: Graphs and digraphs, special types of graphs, trees, isomorphism, connectedness, Euler and Hamilton graphs, planar graphs, Graph Laplacian; graph colouring.

MATH F214 Elementary Real Analysis **3 0 3**

Countability and uncountability of sets; real numbers; limits and continuity; compactness and connectedness in a metric space; Riemann integration; uniform convergence.

MATH F215 Algebra I **3 0 3**

Groups, subgroups, a counting principle, normal subgroups and quotient groups, Cayley’s theorem, automprhisms, permutation groups, and Sylow’s thorems. Rings, ring of real quaternions, ideals and quotient rings, homorphisms, Eculidean rings, polynomial rings, and polynomials over the rational field.

MATH F231 Number Theory **3 0 3**

Primes and factorization; division algorithm; congruences and modular arithmetic; Chinese remainder theorem Euler phi-function and primitive roots of unity; Gauss's quadratic reciprocity law; applications to periodic decimals and periodic continued fractions.

MATH F241 Mathematical Methods **3 0 3**

Integral Transforms: Fourier, Fourier sine/cosine and their inverse transforms (properties, convolution theorem and application to solve differential equation), Discrete Fourier Series, Fast Fourier transform, Calculus of Variation: Introduction, Variational problem with functionals containing first order derivatives and Euler equations, Variational problem with moving boundaries. Integral equations: Classification of integral equations, Voltera equations, Fredholm equations, Greens functions.

MATH F242 Operations Research **3 0 3**

Introduction to Data Processing; Files and File Structures; Indexing Techniques; Sorting, Searching and Merging Techniques; Introduction to Database Management Systems; Design of Information Systems; Emerging trends in Data Processing.

MATH F243 Graphs and Networks **3 0 3**

Basic concepts of graphs and digraphs behind electrical communication and other networks behind social, economic and empirical structures; connectivity, reachability and vulnerability; trees, tournaments and matroids; planarity; routing and matching problems; representations; various algorithms; applications.

MATH F244 Measure and Integration **3 0 3**

Lebesgue measure and integration in real numbers, Convergence and Convergence theorems, absolutely continuous functions, differentiability and integrability, theory of square integrable functions, and abstract spaces.

MATH F266 Study Project **3**

These courses include projects which are oriented towards readings from published literature or books about new frontiers of development or analysis of available database. These courses are normally available to students in second or higher levels. These courses must coterminate with project reports.

MATH F311 Introduction to Topology **3 0 3**

Metric Spaces; Topological Spaces – subspaces, Continuity and homoeomorphism, Quotient spaces and product spaces; separation Axioms; Urysohn’s Lemma and Tietze extension Theorem; Connectedness; Compactness, Tychonoff’s Theorem, Locally Compact Spaces; Homotopy and the fundamental group.

MATH F312 Ordinary Differential Equations **3 0 3**

Existence and uniqueness theorems; properties of linear systems; behaviour of solutions of nth order equations; asymptotic behaviour of linear systems; stability of linear and weakly nonlinear systems; conditions for boundedness and the number of zeros of the nontrivial solutions of second order equations; stability by Liapunov's direct method; autonomous and nonautonomous systems.

MATH F313 Numerical Analysis **3 0 3**

Principles of floating point computations and rounding errors; Systems of Linear Equations: factorization methods, pivoting and scaling, residual error correction method; Iterative methods: Jacobi, Gauss-Seidel methods with convergence analysis; Eigenvalue problems: algorithms with implementation issues; Nonlinear algebraic equation: root finding (bisection, secant, fixed point iteration and Newton-Raphson methods), nonlinear algebraic system (Fixed point iteration, Newton and Newton like methods); Interpolation: Lagrange interpolation techniques, piecewise linear and cubic splines, error estimates; Approximation: uniform approximation by polynomials, data fitting and least squares approximation; Numerical Integration: integration by interpolation, adaptive quadratures and Gauss methods; Initial Value Problems for Ordinary Differential Equations: Euler’s method, single step Runge-Kutta methods, multi-step methods, predictor and corrector scheme, stability and convergence analysis. FDM for Two point BVP.

MATH F314 Algebra II **3 0 3**

Dual spaces, modules, fields, finite fields, extension of fields: algebraic extension, separable and inseparable extension, normal extension, sptitting fields, Galois extension, and Galois group. The algebra of linear transformations, characteristic roots and characteristic vectors, canonical forms: triangular form, nilpotent form, and Jordan form.

MATH F315 Introduction to Statistical Inference **3 0 3**

Parametric point estimation; Unbiasedness; Consistency; Uniform minimum variance unbiased estimator; Method of moments; Maximum likelihood estimation and its properties; Lower bounds for the variance of an estimator; Sufficiency; Factorization theorem; Best equivariant estimators; Tests of hypotheses; Neyman-Pearson lemma; uniformly most powerful (UMP) tests; Likelihood ratio tests; Chi-square tests; Methods for finding confidence intervals.

MATH F316 Matrix Theory and Linear Estimation **3 1 4**

Revision of linear algebra and allied concepts; Generalized inverse; Singular value decomposition their applications; Majorization, Principal components, Canonical correlations; Generalized inverses, Linear model, Estimability; Residual sum of squares; Schur complements, Multivariate normal distribution, quadratic forms and Cochran's theorem; One-way and two-way classifications, general linear hypothesis, Multiple correlation and regression models; Block designs and optimality: reduced form of normal equations, c-Matrix.

MATH F317 Sampling Theory **3 1 4**

Advantages of the sampling method; Principal steps in a sample survey; Role of sampling theory; Probability sampling; Bias and its effects. Simple random sample: definitions and notation; Properties of the estimates; Variances of the estimates; Finite population correction; Estimation of the standard error from a sample; Confidence limits; Validity of the normal approximation; Effect of non-normality on the estimated variance. Sampling for proportions and percentages. Stratified sampling: Estimation of gain due to stratification; Ratio and regression methods of estimation; Unbiased ratio type estimators; Optimality of ratio estimate. Cluster sampling, Two stage sampling, Double sampling.

MATH F341 Introduction to Functional Analysis **3 0 3**

Banach spaces; fundamental theorems of functional analysis; Hilbert space; elementary operator theory; spectral theory for self-adjoint operators.

MATH F342 Differential Geometry **3 0 3**

Curve in the plane and 3D-space; Curvature of curves; Surfaces in 3D-space; First Fundamental form; Curvature of Surfaces; Gaussian and mean Curvatures; Theorema Egreguim; Geodesics; Gauss-Bonnet Theorem.

MATH F343 Partial Differential Equations **3 0 3**

Non linear equations of first order, Charpits Method, Method of Characteristics; Elliptic, parabolic and hyperbolic partial differential equations of order 2, maximum principle, Duhamels principle, Greens function, Laplace transform & fourier transform technique, solutions satisfying given conditions, partial differential equations in engineering & science.

MATH F344 Mathematical Fluid Dynamics **3 0 3**

Introduction to the Fluid Dynamics and Fundamental Concepts, Langrange and Eulerian Descriptions, Continuum hypothesis, Conservation of Mass based on different approaches, Equation of Continuity in different Coordinates,Potential Flow, Laplace Equation, one-,two- and three-dimensional flow, Conservation of Linear Momentum,Euler's Equation,Bernoulli's equation, Constitutive equations for Newtonian Fluid, Navier-Stokes Equations, First Law of Thermodynamics, Reynolds number, Exact Solution of Navier-Stocks Equation, Boundary Layer Approximations, Setting up the Boundary-Layer Equations, Limit Equation For the Flat Plate, Discussion of Blasius' Equation, Description of Flow Past a Circular Cylinder, Decay of a Laminar Shear Layer.

MATH F353 Statistical Inference and Applications **3 0 3**

Review of elements of probability and statistical methods, Classical Decision theory including parametric and non-parametric methods for testing of hypotheses, Analysis of Variance: One way and two way classifications, Design of experiments: Analysis of Completely randomized design, Randomized block design and Latin square design with one or more missing values, Statistical Quality control for variables and measurements.

MATH F354 Complex Analysis **3 0 3**

A rigorous treatment of the theory of analytic functions of complex variables including Cauchy's theorems; maximum modulus theorem; the principles of argument; Jensen's formula; Mittag Lefler theorem; Weierstrass canonical products and analytic continuation.

MATH F366 Lab Project **3**

MATH F367 Lab Project **3**

These courses include projects involving laboratory investigation or laboratory development in the students discipline or interdisciplinary areas. These courses are normally available to students in third or higher levels. These courses must coterminate with project reports.

MATH F376 Design Project **3**

MATH F377 Design Project **3**

These courses are intended to impart training in design of product/ process or other artifact to the students in the discipline or interdisciplinary areas. These courses are normally available to students in third or higher levels. These courses must coterminate with project reports.

MATH F378 Advanced Probability Theory **3 0 3**

Measure theoretic probability and probability space, Law of large numbers and independence, convergence, Central limit theorems, Higher dimensional limit theorems, Random walks and their properties, Martingale and their properties, Martingale convergence theorem, Radon-Nikodym derivative, Doob's inequality, Backward martingales, Markov chain and their properties, finite state ergodicity, recurrence and transience.

MATH F420 Mathematical Modeling **3 1 4**

Review of ODEs: local existence, uniqueness results (without proof), Gronwall's inequality, continuation of solution (without proof),equilibrium points, linearised stability, phase-plane analysis and Liapunov stability (without proof); Mathematical Modelling: Principle of modelling, Dimensional analysis and scaling; Discrete Models: basic theory of difference equations (steady state, stability and critical parameters), Difference Equations applied to Biological models (Cell division and insect population, single population), two species interactions, Nicholson Baily model; Modeling through ODEs of first-order: growth and decay models, compartment models; Modeling through systems of ODEs: bacterial growth in Chemostat, Glucose-Insulin Kinetics, Pray-Predator systems, SIR model, Hodgkin-Huxley nerve conduction model, Fitzhugh-Nagumo model of for Neural Impulses with analysis (limit cycle, oscillations); Modelling through PDEs: basics of modelling (conservation principles), diffusion based population dispersal model, Chemostatic motion of micro-organisms.

Lab Component: Group projects on Case Studies.

MATH F421 Combinatorial Mathematics **3 0 3**

Advanced theory of permutations and combinations; elementary counting functions; theory of partitions; theorems on choice including Ramsey's theorem; the mobius function; permutation groups; Polya's theorem and Debrauijn's generalisation; graphical enumeration problems.

MATH F422 Numerical Methodology for Partial Differential Equations **3 1 4**

Review of linear PDEs: First order linear scalar equation and explicit solution by characteristic method; Classification of 2nd order linear PDEs and maximum principle for Laplace and heat equations.Finite differences: Grids, Finite-difference approximations to derivatives. Linear Transport Equation: Upwind, Lax-Wendroff and Lax-Friedrich schemes,von-Neumann stability analysis, CFL condition, Lax-Richtmyer equivalence theorem ; . Heat Equation: Initial and boundary value problems (Dirichlet and Neumann), Explicit and implicit methods (Backward Euler and Crank-Nicolson schemes) with consistency and stability, Discrete maximum principle, Convergence ; Poisson's Equation: Finite difference scheme for boundary value problems, Discrete maximum principle, Iterative methods for linear systems (Jacobi, Gauss-Seidel, SOR methods and Conjugate Gradient method), Peaceman-Rachford algorithm (ADI) for linear systems. Wave Equation: Explicit schemes and their stability analysis.

Lab Component: Implementation of algorithms discussed in this course

MATH F423 Introduction to Algebraic Topology **3 0 3**

Homotopy; Fundamental group and Computation; Covering Spaces; Universal Covering Spaces; Simplicial Complexes; Simplicial Homology and Computation.

MATH F424 Applied Stochastic Process **3 1 4**

Definition and examples of Stochastic Processes (SPs), classification of random processes according to state space and parameter space, types of SPs, elementary problems; Stationary Process: Weakly stationary and strongly stationary processes, moving average and autoregressive processes; Martingales: definition and examples of martingales; Markov Chains: Transition probability, classification of states and chains, stability of Markov chains, irreducibility, stationary distribution ergodic theorem; Continuous-time Markov Chains (CTMCs): Poisson process, birth-death process and their applications; Continuous time and continuous state space: Brownian motion, Wiener process and applications; Renewal processes in discrete and continuous time; Renewal reward process; Branching Processes; Galton-Watson branching process and its properties.

MATH F425 Numerical Linear Algebra **3 1 4**

Matrix algebra, conditioning, condition number, vector and matrix norms, perturbation theory of linear systems, stability of numerical algorithms, Cholesky decomposition, floating point arithmetic and its error analysis, singular value decomposition (SVD), algebraic and geometric properties of SVD, least square solutions, Moore Penrose inverse, Rank deficient least squares problems, Sensitivity analysis of SVD and least-squares problems, Householder matrices and transformation, QR method, Iterative methods with iterative refinement, Krylov subspace method, Arnoldi iteration, Low rank approximations.

Pre-requisite: MATH F112 Mathematics II

MATH F426 Mathematical Theory of Finite Element Methods **3 1 4**

Hilbert spaces, Sobolev Spaces, Variational formulation of elliptic boundary value problems, Lax-Milgram theorem, Error estimates, Construction of FE spaces, Polynomial approximations, interpolation errors, Aubin-Nitsche duality argument, Parabolic initial and boundary value problems: Semi-discrete and fully discrete schemes, error estimates.

MATH F427 Statistical Simulation and Data Analysis **3 1 4**

Review of probability concepts; Pseudorandom number generation; Generating discrete random variables – Poisson and binomial random variables; Generating continuous random variables: Polar method for generating normal random variables; Discrete event simulation approach – single-server and two-servers queueing system, inventory model; Statistical analysis of simulated data – bootstrapping technique for estimating mean square errors; Several ways of variance reduction; Concepts of stratified sampling; Statistical goodness of fit tests – two sample problem; Markov chain Monte Carlo methods; The Hastings–Metropolis algorithm; Gibbs sampler; Continuous time Markov chains and a queueing loss model; Simulated annealing; Methods of data analysis.

MATH F428 Time Series Analysis and Forecasting **3 1 4**

The course reviews Extrapolative and Decomposition Models, Introduction to Box–Jenkins Time Series Analysis, ARIMA Models, which remains the most commonly used statistical technique in Time Series Analysis. The remainder of the course considers various practical aspects of the principles behind modern forecasting techniques. A one-hour lab will be conducted every week. Students will learn how to explore and analyze different types of Time Series data using R programming.

MATH F431 Distribution Theory **3 0 3**

C-infinity functions, distributions and their derivatives; support, convolution and regularization; distributions of finite order; multiplication of distributions; Fourier transforms of distributions; temperate distributions and their Fourier transforms; fundamental solutions.

MATH F432 Applied Statistical Methods **3 0 3**

Review of estimation and testing of hypotheses; Simple and multiple regression methodology through method of least squares, Multicollinearity and residual analysis, Categorical data handling through logistic regression; Multivariate data analysis by Hoteling T^2, Mahalanobis D^2, discriminant analysis, cluster analysis and factor analysis; Data handling and forecasting time series data by various components time series methodology; Statistical Quality Control of variables and attributes control charts; Non parametric data handling through Kruskal walls test, Mann Whitney and KS two sample test.

MATH F441 Discrete Mathematical Structures **3 0 3**

One or more of the interrelated topics will be covered from the following: graphs, designs, codes, shift register sequences, groups, fields, Boolean algebras, analysis of algorithms, Fast Fourier Transform etc. providing a fertile ground for interaction between mathematics and modern areas of computer science. The selection of the topics will depend upon the circumstance and current interest of faculty.

MATH F444 Numerical Solutions of Ordinary Differential Equations **3 0 3**

Introduction to ODEs, Numerical Techniques for One Step Methods, Convergence and Absolute Stability, Numerical techniques for Linear Multi-Step Methods, Zero Stability, Consistency, Convergence, Predictor-Corrector methods, Absolute Stability of Predictor-Corrector methods, Stiff ODEs and its numerical methods, Finite Difference Methods to Linear and Nonlinear Boundary Value Problems, Stability and Convergence Analysis, Differential Algebraic Equations, Numerical techniques for Differential Algebraic Equations, Introduction to One dimensional Finite Element Methods, Comparison between Finite Difference Methods and Finite Element Methods, Variational formulation, Finite Element Approximation, Approximation Errors, Convergence of solution, Order of Convergence.

MATH F445 Mathematical Fluid Dynamics **3 0 3**

Introduction to the Fluid Dynamics and Fundamental Concepts, Lagrange and Eulerian Descriptions, Continuum hypothesis, Conservation of Mass based on different approaches, Equation of Continuity in different Coordinates, Potential Flow, Laplace Equation, one-, two- and three-dimensional flow, Conservation of Linear Momentum, Euler's Equation, Bernoulli's equation, Constitutive equations for Newtonian Fluid, Navier-Stokes Equations, First Law of Thermodynamics, Reynolds number, Exact Solution of Navier-Stokes Equation, Boundary Layer Approximations, Setting up the Boundary-Layer Equations, Limit Equation For the Flat Plate, Discussion of Blasius' Equation, Description of Flow Past a Circular Cylinder , Decay of a Laminar Shear Layer

MATH F456 Cosmology **3 0 3**

History of cosmological ideas, Observational overview of the universe, Expansion of the universe, Newtonian gravity, Friedman equation, the fluid and acceleration equations, Geometry of the universe, Infinite and observable universe, Big bang, Simple cosmological models, Hubble law, redshift, Observational parameters, the cosmological constant, the age of the universe, weighing the universe, dark matter, CMB, the early universe, Nucleosynthesis, Inflationary universe, Initial singularity, standard cosmological model, general relativistic cosmology, classic cosmology, neutrino cosmology, baryogensis, structure of the universe.

MATH F471 Nonlinear Optimization **3 0 3**

Introduction; convexity and cones; Kuhun Tucker theory; unconstrained and constrained optimization; gradient methods; polynomial optimization; penalty function; generalized convex functions; duality in nonlinear programming; optimality criterion for generalised convex functions; fractional programming.

MATH F481 Commutative Algebra **3 0 3**

Modules; direct sums and products; finitely generated modules, exact sequences; tensor product of modules; rings and modules of fractions; localization; Noetherian modules and primary decompositions; integral dependence and valuation theory; integrally discrete valuation rings and Dedekind domains; fractional ideals.

MATH F491 Special Projects **3**

This is an unstructured open-ended course where under the overall supervision of an instructor-in-charge, batches of students will be attached to different instructors. Each batch will work on a specific time-bound project which is of basic or peripheral concern of his discipline. Each student must submit a project report as a culmination of his endeavour and investigation. The instructor- in-charge will determine the choice of the project and also whether or not the project report is to be submitted jointly by a group or individually by a student. The course will aim to evaluate student's actual ability to use the fundamentals of knowledge and to meet new unknown situations as demonstrated by the students' interaction with the instructors and instructor-in- charge and aggregated in the project report. The instructor-in- charge may assign specific hours for formal brain-storming sessions.

MATH F492 Wavelet analysis and applications **3 1 4**

Haar wavelet bases, Multiresolution analysis, Orthonormal wavelets from MRA, Orthonormal spline wavelets, Fast wavelet transforms, Biorthogonal wavelet bases, Compactly supported wavelets, The Daubechies scaling functions, Coding signals by wavelet transform, Filter banks, Condition number of a matrix , Wavelet Galerkin method.

BITS F314 Game Theory and Its Applications **3 0 3**

Strategic thinking, Rational choice, Dominance, Rationalizability, Nash equilibrium, Best response functions, Duopoly models and Nash equilibrium therein, Electoral competition, Pure strategy, Mixed strategy, Extensive forms, Sub-game perfect Nash equilibrium, Bayesian Nash equilibrium, Select Applications of Game Theory.

BITS F316 Nonlinear Dynamics and Chaos **3 0 3**

Chaos – definitions, characteristics, and measures; Examples of chaotic systems; Nonlinear dynamics and chaos – state space, Poincare sections, Iterated maps, Period-doubling; Quasi-periodicity, Intermittency, fractals; computer simulations of chaotic systems; Selected topics and applications of chaos theory; Examples will be drawn from different disciplines in science, engineering, and social sciences.

BITS F343 Fuzzy Logic and Applications **3**

Fuzzy sets, fuzzy binary relations; fuzzy logic, fuzzy reasoning; applications in decision making, control theory, expert systems, artificial intelligence etc.

BITS F386 Quantum Information and Computation **3 0 3**

History and scope, introduction to quantum information, quantum bits (qubits), quantum parallelism, teleportation etc. Basic ideas of quantum systems, two-state systems, evolution of states, superposition, entanglement, quantum measurement, decoherence. Basic ideas of computation theories and models, computational resources, complexity. Quantum Gates: single qubit, multiple qubit gates, controlled gates, universal gates, measurement. Quantum algorithms, Deutsch', Shor's and Grover's Algorithms, quantum circuits. Quantum Fourier Transform and applications, Quantum Search Algorithm. Physical Implementation of quantum computation. Compression and transmission of quantum information, quantum noise, error-correction, coding and cryptography, complexity, fault-tolerant computation.

BITS F463 Cryptography **3 0 3**

Objectives of cryptography; ciphers – block and stream; mathematical foundations – modular arithmetic, finite fields, discrete logarithm, primality algorithms; RSA; digital signatures; interactive proofs; zero–knowledge proofs; probabilistic algorithms; pseudo-randomness.

BITS F232 Foundations of Data Structures and Algorithms **3 1 4**

Algorithm Analysis – Mathematical preliminaries, Sorting Algorithms, Search Algorithms, Linear Structures, Non-Linear Structures, Hashing, Non-Linear Structures, Graphs and Algorithms.

CS F364 Design and Analysis of Algorithms **3 0 3**

Basic Design Techniques – Divide-and-Conquer, Greedy, Dynamic Programming (Examples, Analysis, General Structure of Solutions, Limitations and Applicability). Specialized Design Techniques: Network Flow, Randomization (Examples, Analysis, Limitations). Complexity Classes and Hardness of Problems – P, NP, Reductions, NP-hardness and NP-Completeness, Reduction Techniques, Basic NP-complete problems. Design Techniques for Hard Problems – Backtracking, Branch-and-Bound, and Approximation (General approaches and structure of solution, Analysis, and Limitations). Linear Programming – LP Problem and Simplex Algorithm, Approach for using LP for modeling and solving problems. Introduction to Design and Analysis of Parallel and Multi-threaded Algorithms.

3 0 3

MAC F211 Linear Algebra and Its Applications

Quick Review of Vector Spaces and Linear Transformations: Basis and dimension, rank-nullity theorem, change of basis; Inner product spaces: Cauchy Schwarz's inequality, Orthonormal basis, Gram-Schmidt orthonormalization, QR decomposition, orthogonal projection with projection theorem, General Least-squares problem, Discrete Fourier Transform; Norms of vectors, functions, and matrices, matrix decompositions; Eigenvalues and eigenvectors, Diagonalization, Spectral Theorem, Cayley-Hamilton Theorem, Primary Decomposition theorem, Jordan canonical forms (without proof); Singular value decomposition and applications: Reduced SVD, norms, condition number, and Rank via SVD, Moore-Penrose inverse, Principal Component Analysis, and Lowrank approximations, least-squares solutions to linear systems.

Pre-requisites: MATH F112: Mathematics II

MAC F244 Stochastic Calculus and Application to Finance **3 0 3**

Overview of financial markets, derivative securities, discrete-time binomial model, arbitrage, hedging and replicating portfolios, riskneutral probabilities and pricing formula, market completeness, concept of probability as measure, filtering, etc., stochastic processes, conditional expectation, martingales, Markov processes, Brownian motion and quadratic variation, Ito's integral and calculus, replicating portfolios and hedging in continuous time, Black-Scholes-Merton formulae, change of measure, Girsanov's theorem, risk-neutral pricing pricing and existence of risk-neutral measure, market completeness and uniqueness of riskneutral measure, Markov property, Feyman-Kac theorem, local volatility and stochastic volatility models.

Pre-requisites: MATH F113: Probability and Statistics *OR* MATH F211: MATHEMATICS-III *OR* MATH F214: Elementary Real Analysis

MAC F313 Statistical Data Analysis **3 1 4**

Graphical Representation of one- and two-dimensional data; simulation from common distributions including binomial, Poisson, normal, gamma exponential; inverse transform and acceptance-rejection method; goodness of fit tests; tests for independence; simple linear regression and least squares, MLE for regression, residual analysis; multiple linear regression, and variable selection; Generalized linear models, classification, logistic regression, LDA, QDA; Monte-Carlo simulation and integration; Bayes' theorem and Bayesian learning, Frequentist versus Bayesian and simple implementation.

Lab Component: Introduction to R programming and Implementations of algorithms discussed in this course.

Pre-requisites: MATH F113: Probability and Statistics

MAC F411 Computation of Option Pricing Models **3 1 4**

Review of financial market and options: arbitrage, options (European option, american option), interest rate and present value, random nature of stock markets and simple asset price model, Ito Lemma (without proof) and elimination of randomness; Basic Option theory: value of option, put-call parity; Black-Scholes PDE: European option, on dividend paying assets, American options, Hedging and implied volatility; Explicit Solution of Black Scholes equation; American option as free boundary problem and formulation as variational inequality; Finite Difference methods for European options: Explicit Scheme with stability, convergence and probabilistic interpretation, implicit schemes (backward Euler, Crank-Nicolson scheme with stability and convergence; FDM for American options with projected SOR and convergence; pricing of Exotic options; Monte-Carlo for option valuation.

Lab Component: Implementation of European, American, and exotic options. Monte-Carlo Simulation.