MATHEMATICS AND STATISTICS

Professors

Bahuguna D.	dhiren - 7053
Banerjee M	mohua – 7634
Chandra Peeyush	peeyush - 7285
Dutt Pravir	pravir – 7074
Dhariyal I D	idd – 7692
Dutta Joydeep	jdutta – 7568
Ghorai S	sghoria – 7461
Gupta Manjul	manjul – 7963
Kadalbajoo M K	kadal – 7732
Kapoor G P	gp – 7609
Kundu D (HEAD)	kundu – 7141
Lal A K	arlal – 7662
Madan Shobha	madan – 7402
Maloo A K	akmaloo – 7813
Misra Neeraj	neeraj – 7087
Mitra A	amitra – 6064
Rawat Rama	rrawat – 7466
Rathore R K S	rksr – 7228
Rathish Kumar B V	bvrk – 7660
Shunmugaraj P	psraj – 7297
Sinha Prawal	prawal - 7213

Associate Professors

Santhanam G	santhana – 7433
Banerjee Malay	malay – 6517
Dar Aparna	adar – 7926
Dutta S	sudipta – 7905
Mitra S	smitra – 6044
Mohanty Parasar	Parasar – 6139
Nilakantan N	nandini – 7066
Shalabh	shalab – 7905

Assistant Professors

Anand A	akasha – 7880
Chavan Sameer	chavan – 7158
Muthukumar T	tmk – 7911

Convenor, DUGC : Ghorai S – sghorai 7461

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The Department of Mathematics and Statistics (earlier known as the Department of Mathematics) came into existence together with IIT Kanpur in 1960. Right from its inception the Department shares the vision of the Institute in striving for excellence in research and teaching activities. The department has succeeded in this endeavor by producing highly qualified and motivated mathematicians who are providing leadership in different educational institutions and R&D organizations in India and abroad. The vibrant academic environment of the department is nurtured by strongly motivated faculty and students.

The broad areas of research specialization in the department are: Algebra, Analysis, Biomathematics, Complex Dynamics, Topology, Combinatorics, Mathematical Logic, Geometry, Differential Equations, Optimization, Fluid Mechanics, Mathematical Modeling, Computational Fluid Dynamics, Parallel Computing, Image Processing and Probability and Statistics.

The current pace of advancement of technology needs a coherent back up of basic science education and research. The vibrant academic ambience and research infrastructure of IIT Kanpur provides an opportunity to pursue research career in frontier areas of basic sciences as well as in interdisciplinary areas of science and technology. The department encourages interdisciplinary trends with the help of the expertise available at this Institute. In the coming decade, apart from the existing areas, the department intends to develop areas related to mathematical aspects of computing science in all its manifestations.

ACADEMIC PROGRAMMES

At the Master's level, the department has a 5 year M.Sc. (Integrated) Programme in Mathematics and Scientific Computing. The admission to this programme is through the Joint Entrance Examination (JEE). The philosophy behind this programme is to provide young students with an exposure to Engineering Sciences during the first two years as a core programme common to all undergraduate students of the Institute. Thereafter, the students of this programme are trained with the professional courses in the department up to the Master's level.

The department also has M.Sc. (2 year) programmes in (i) Mathematics and (ii) Statistics, where the students are selected with a Bachelor's degree though a Joint Admission Test (JAM) common to all IIT's. This curriculum eventually merges with that of M.Sc. (integrated) programme.

The department offers Ph.D. programmes in (i) Mathematics and (ii) Statistics. The admissions to these programmes are through GATE/CSIR/NET examination followed by a departmental interview/ test. These programmes are dynamic in nature and are flexible enough to allow students to pursue their own interests even outside the department. The scope of these programmes is to provide comprehensive knowledge and training in the fundamental principles. It also trains them in the mathematical aspects of computing science. The department has a well-equipped PC lab, providing computing and remote access facilities exclusively to the department students. It also has a Parallel Computing Lab and its own computer server. The department has well stocked departmental library. The P. K. Kelkar Library of the Institute has been identified as Regional Library for Mathematics by the National Board for Higher Mathematics (NBHM).

M.Sc. Integrated (Mathematics and Scientific Computing)

	S E M E S T E R									
	FIRST	**SECOND**	**THIRD**	**FOURTH**	**FIFTH**	**SIXTH**	**SEVENTH**	**EIGHTH**	**NINTH**	**TENTH**
C	CHM101	TA101	MTH203N	HSS-I-2	MTH301				MTH598	MTH599
O	PHY101	PHY103	CHM201N	ESO209	MTH311	MTH304	MTH403			
U	PHY102	MTH102	TA201N	MTH202	MTH401	MTH306	MTH421			
R	MTH101	ESC102	ESO211	MTH204		MTH308	MTH423			
S	ESC101	MTH100	MTH201	MTH302						
E	PE101	PE102								
	HSS-I-1/ ENG112									

In addition to above, the student must complete the following credits:

HSS-2 08 Credits
GE * 28 Credits
NDE 08 Credits
and

DE-12 Credits & OE – 16 Credits **OR** DE- 8 Credits & OE-20 Credits.

*** Group Electives** – Department prescribes two lists of courses from which 28 credits have to be passed, with a minimum of 8 credits from either list.

The above template is valid for Y7 batch students or students joining later in Maths & Scientific Computing. The students of other batches must contact the DUGC Convener, Maths & Scientific Computing for their course templates.

CHM 101	Chemistry Lab	PHY 101	Physics Lab
HSS	Humanities & Social Sciences	PHY 102	Physics - I
MTH 101	Mathematics - I	ESC 101	Fundamentals of Computing
PE 101	Physical Education – I	ENG 112	Remedial English
TA 101	Engineering Graphics	PHY 103	Physics - II
MTH 102	Mathematics - II	ESC 102	Introduction to Electronics
PE 102	Physical Education - II	MTH 203	Mathematics – III
CHM 201	Chemistry	TA 201	Manufacturing Processes
ESO 211	Data Structures and Algorithms - I	MTH 201	Linear Algebra
MTH 202	Discrete Mathematics	ESO 209	Probability and Statistics
MTH 204	Algebra - I	MTH 302	Mathematical Logic
MTH301	Analysis – I	MTH 311	Probability Theory – I
MTH 401	Theory of Computation	MTH 304	Topology
MTH 306	Linear Programming and Extensions	MTH 308	Principles of Numerical Computations
MTH 403	Complex Analysis	MTH 421	Ordinary Differential Equations
MTH 423	Introduction to Continuum Mechanics	MTH 598/599	Projects – I & II

Group Electives

Group A: MTH 404, MTH 405, MTH 411, MTH 424, MTH 611, MTH 612, MTH 620, MTH 621, MTH 624, MTH 627, MTH 648, MTH 649

Group B: MTH 412, MTH 416, MTH 417, MTH 418, MTH 428, MTH 506, MTH 511, MTH 513, MTH 514, MTH 515, MTH 517, MTH 522, MTH 523, MTH 524, MTH 603, MTH 657, MTH 658, MTH 686, MTH 691, MTH 692, MTH 693, MTH 698

MTH 404	Analysis – II
MTH 405	Functional Analysis
MTH 411	Probability Theory – II
MTH 424	Partial Differential Equations
MTH 611	Algebra – II
MTH 612	Commutative Algebra
MTH 620	Measure Theory
MTH 621	Fourier Analysis
MTH 624	Differential Manifolds & Lie Groups
MTH 627	Applied Harmonic Analysis
MTH 648	Differential Geometry
MTH 649	Algebraic Topology

MTH 412	Stochastic Processes
MTH 416	Regression Analysis
MTH 417	Sampling Theory
MTH 418	Inference – I
MTH 428	Mathematical Methods
MTH 506	Optimization
MTH 511	Statistical Simulation & Data Analysis
MTH 513	Analysis of Variance
MTH 514	Multivariate Analysis
MTH 515	Inference – II
MTH 517	Time Series Analysis
MTH 522	Finite Element Method
MTH 523	Fluid Mechanics
MTH 524	Algorithms
MTH 603	Mathematical Modelling
MTH 657	Graph Theory
MTH 658	Nonlinear Dynamical Systems
MTH 686	Nonlinear Regression
MTH 691	Numerical Linear Algebra
MTH 692	Numerical Solutions to ODEs
MTH 693	Numerical Solutions to PDEs
MTH 698	Parallel Numerical ALgorithms

STRUCTURE OF THE M.Sc. (TWO YEAR) PROGRAM IN MATHEMATICS

YEAR I		YEAR II	
Semester I	Semester II	Semester III	Semester IV
MTH 201	MTH 204	MTH 403	OE - II
MTH 301	MTH 304	MTH 405	MTH 306
MTH 409	MTH 308	MTH 421	MTH 424
MTH 423	MTH 404	DE - I	DE - II
MTH 428	ESO 209	OE - I	MTH 598/ DE - III

STRUCTURE OF THE M.Sc. (TWO YEAR) PROGRAM IN STATISTICS

YEAR I		YEAR II	
Semester I	Semester II	Semester III	Semester IV
MTH 311	MTH 306	MTH 513	MTH 514
MTH 409	MTH 412	MTH 515	MTH 516
MTH 413	MTH 411	MTH 517	MTH 511
MTH 415	MTH 416	DE - I	OE - II
MTH 417	MTH 418	OE - I	MTH 598/ DE-II

ESO 209	Probability & Statistics
MTH 201	Linear Algebra
MTH 204	Algebra-I
MTH 301	Analysis-I
MTH 304	Topology
MTH 306	Linear programming & Extensions
MTH 308	Principles of Numerical Computations
MTH 403	Complex Analysis
MTH 404	Analysis-II
MTH 405	Functional Analysis
MTH 409	Computer Prog. & Data Sructures
MTH 421	Ordinary Differantial Equations
MTH 423	Introduction to Continuum Mechanics
MTH 424	Partial Differential Equations
MTH 428	Mathematical Methods
MTH 598	Project
MTH 311	Probability Theory-I
MTH 411	Probability Theory-II
MTH 412	Stochastic Processes
MTH 413	Real Complex Analysis
MTH 415	Matrix Theory & Linear Estimation
MTH 416	Regression Analysis
MTH 417	Sampling Theory
MTH 418	Inference-I
MTH 511	Statistical Simulations & Data Analysis
MTH 513	Analysis of Variance
MTH 514	Multivariate Analysis
MTH 515	Inference-II
MTH 516	Non-parameteric Inference
MTH 517	Time series Analysis

DE	Departmental Elective
OE	Open Elective (any course in any Department)
GE	Group Electives*

COURSE DESCRIPTION

ESO 209 **PROBABILITY AND STATISTICS** **Prereq. MTH-101**
L-T-P-D-[C]
3-1-0-1-[4]

Probability:- Axiomatic definition, Properties. Conditional probability, Bayes rule and independence of events. Random variables, Distribution function, Probability mass and density functions, Expectation, Moments, Moment generating function, Chebyshev's inequality. Special distributions: Bernoulli, Binomial, Geometric, Negative Binomial, Hypergeometric, Poisson, Uniform, Exponential, Gamma, Normal, Joint distributions, Marginal and conditional distributions, Moments, Independence of random variables, Covariance, Correlation, Functions of random variables, Weak law of large numbers, P. Levy's central limit theorem (i.i.d. finite variance case), Normal and Poisson approximations to binomial, Statistics:- Introduction: Population, Sample, Parameters. Point Estimation: Method of moments, MLE, Unbiasedness, Consistency, Comparing two estimators (Relative MSE). Confidence interval estimation for mean, difference of means, variance, proportions, Sample size problem, Test of Hypotheses:-N-P Lemma, Examples of MP and UMP tests, p-value, Likelihood ratio test, Tests for means, variance, Two sample problems, Test for proportions, Relation between confidence intervals and tests of hypotheses, Chi-square goodness of fit tests, Contingency tables, SPRT, Regression Problem:- Scatter diagram, Simple linear regression, Least squares estimation, Tests for slope and correlation, Prediction problem, Graphical residual analysis, Q-Q plot to test for normality of residuals, Multiple regression, Analysis of Variance: Completely randomized design and randomized block design, Quality Control: Shewhart control charts and Cusum charts.

MTH 100 **INTRODUCTION TO PROFESSION** **Prereq. None**
L-T-P-D-[C]
2-0-0-0-[0]

Mathematical thought process: Proofs by construction, existence, specialization, induction, contradiction, Abstraction, Sets: Russel's paradox, Axiom of Choice, Counting, Infinity, Continuum Hypothesis, Numbers:Real numbers, Cantor's diagonalization arguments, e, p, Complex numbers, Fundamental theorem of algebra, Fermat's last theorem, Goldbach's conjecture, Analysis: Existence of nowhere differentiable functions, Zeno's paradox-infinite series, Geometry: Euler's theorem, Mobius strip, Trisection of an angle, Squaring a circle, Euclid's parallel postulate, Non-Euclidean geometries, Mathematical structures: Euclidean structure, Metric spaces, Hilbert spaces, Topology, Groups, Rings, Modules, Vector spaces, Algebraic geometry, Networks, Map coloring, Graphs, Computation:Iteration Approximations, Computability, Church-Turing thesis

MTH 101 **MATHEMATICS-I** **Prereq. None**
L-T-P-D-[C]
3-1-0-1-[4]

Real numbers, Sequences; Series; Power series, Limit, Continuity; Differentiability, Mean value theorems and applications; Linear Approximation, Newton and Picard method, Taylor's theorem (one variable), Approximation by polynomials, Critical points, convexity, Curve tracing, Riemann Integral, fundamental theorems of integral calculus, Improper integrals, Trapezoidal and Simpson's rule; error bounds, Space coordinates, lines and planes, Polar coordinates, Graphs of polar equations; Cylinders, Quadric surfaces, Volume, Area, length; Continuity, Differentiability of vector functions, arc length; Curvature, torsion, Serret-Frenet formulas, Functions of two or more variables, partial derivatives Statement only, of Taylor's theorem and criteria for maxima/Minima/saddle points, Double, triple integrals, Jacobians; Surfaces, integrals, Vector Calculus, Green, Gauss, Stokes Theorems.

MTH 102 **MATHEMATICS-II** **Prereq. MTH 101**

L-T-P-D-[C]
3-1-0-1-[4]

Matrices: matrix operations (Addition, Scalar Multiplication, Multiplication, Transpose, Adjoint and their properties; Special types of matrices (Null, Identity, Diagonal, Triangular, Symmetric, Skew-Symmetric, Hermitian, Skew-Hermitian, Orthogonal, Unitary, Normal), Solution of the matrix Equation Ax = b; Row-reduced Echelon form, Determinants and their properties, Vector Space $R^n(R)$; Subspaces; Linear Dependence/Independence; Basis; Standard Basis of R^n; Dimension; Coordinates with respect to a basis; Complementary Subspaces; Standard Inner product; Norm; Gram-Schmidt Orthogonalization Process; Generalization to the vector space $C^n(C)$, Linear Transformation from R^n to R^m (motivation, X* AX); Image of a basis identifies the linear transformation; Range Space and Rank; Null Space and Nullity; Matrix Representation of a linear transformation; Structure of the solutions of the matrix equation Ax = b; Linear Operators on R^n and their representation as square matrices; Similar Matrices and linear operators; Invertible linear operators; Inverse of a non-singular matrix; Cramer's method to solve the matrix equation Ax = b; Eigenvalues and eigenvectors of a linear operator; Characteristic Equation; Bounds on eigenvalues; Diagonalizability of a linear operator; Properties of eigenvalues and eigenvectors of Hermitian, skew-Hermitian, Unitary, and Normal matrices (including symmetric, skew-symmetric, and orthogonal matrices), Implication of diagonalaizability of the matrix $A + A^T$ in the real quadratic form X^TAX; Positive Definite and Semi-Positive Definite matrices, Complex Numbers, geometric representation, powers and roots of complex numbers, Functions of a complex variable, Analytic functions, Cauchy-Riemann equations; elementary functions, Conformal mapping (for linear transformation); Contours and contour integration, Cauchy's theorem, Cauchy integral formula; Power Series, term by term differentiation, Taylor series, Laurrent series, Zeros, singularities, poles, essential singularities, Residue theorem, Evaluation of real integrals and improper integrals.

MTH 201 **LINEAR ALGEBRA** **Prereq. MTH 102**

L-T-P-D-[C]
3-1-0-0-[4]

Fields and linear equations. Vector spaces. Linear transformations and projections, Determinants. Elementary canonical forms: diagonalization, triangulation, primary decomposition etc. Secondary decomposition theorem, Rational canonical forms, Jordan canonical forms and some applications. Inner product spaces, Selfadjoint, Unitary and normal operators, Orthogonal projections. Bilinear forms, Symmetric, Skew-symmetric, Positive and semi-positive forms etc.

MTH 202 **DISCRETE MATHEMATICS** **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Permutations and combinations and basic definitions. Generating functions. Polya's enumeration theory. Recurrence relations. Principle of inclusion and exclusion. Balanced incomplete block design. Difference sets. System of distinct representatives. Orthogonal Latin squares. Hadamard matrices.

MTH 203 **MATHEMATICS-III** **Prereq. MTH 102**

L-T-P-D-[C]
3-1-0-1-[4]

Introduction and Motivation to Differential Equations, First Order ODE y'=f(x,y)- geometrical Interpretation of solution, Equations reducible to separable form, Exact Equations, Integrating factor, Linear Equations, Orthogonal trajectories, Picard's Theorem for IVP (without proof) and Picard's iteration method, Euler' Method, Improved Euler's Method, Elementary types of equations. F(x,y,y') = 0; not solved for derivative, Second Order Linear differential equations: fundamental system of solutions and general solution of homogeneous equation. Use of Known solution to find another, Existence and uniqueness of solution of IVP, Wronskian and general solution of non-homogeneous equations. Euler-Cauchy Equation, extensions of the results to higher order linear equations, Power Series Method - application to Legendre Eqn., Legendre Polynomials, Frobenious Method, Bessel equation, Properties of Bessel functions, Sturm-Liouville BVPs, Orthogonal functions, Sturm comparision Theorem, Laplace transform, Fourier Series and Integrals, Introduction to PDE, basic concepts, Linear and quasilinear first order PDE, second order PDE and classification of second order semilinear PDE (Canonical form), D' Alemberts formula and Duhamel's principle for one dimensional wave equation, Laplace's and Poisson's equations, Maximum principle with application, Fourier Method for IBV problem for wave and heat equation, rectangular region, Fourier method for Laplace's equation in three dimensions, Numerical methods for Laplace's and Poisson's equations.

MTH 204 **ALGEBRA** **Prereq. MTH 203 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Binary operation, and its properties, Definition of a group, Examples and basic properties. Subgroups, Coset of a subgroup, Lagrange's theorem. Cyclic groups, Order of a group. Normal subgroups, Quotient group. Homomorphisms, Kernel Image of a homomorphism, Isomorphism theorems. Permutation groups, Cayley's theorems. Direct product of groups. Group action on a set, Semi-direct product. Sylow' theorems. Structure of finite abelian groups. Applications, Some nontrivial examples. Rings: definition, Examples and basic properties. Zero divisors, Integral domains, Fields, Characteristic of a ring, Quotient field of an integral domain. Subrings, Ideals, Quotient rings, Isomorphism theorems. Ring of polynomlals. Prime, Irreducible elements and their properties, UFD, PID and Euclidean domains. Prime ideal, Maximal ideals, Prime avoidance theorem, Chinese remainder theorem.

MTH 215 **NUMBER THEORY** **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Divisibility, Primes, Congruences, Residue systems, Primitive roots; Quadratic reciprocity, Some arithmetic functions, Farey fractions, Continued fractions, Some Diophantine equations, Bertrands postulate and the partition function.

MTH 247 **ELEMENTARY DECISION THEORY** **Prereq. MTH 203 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Utility and loss functions; The prior information; Basic principles of making decisions under uncertainity; Bayes and Minimax decision rules; Prior and posterior analysis; Applications to classical statistical inference procedures; Sequential procedures.

MTH 300 **BASIC STRUCTURE OF MATHEMATICS** **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Finite and Infinite Sets: Finite sets, Countable sets, Uncountable sets. Groups and Symmetry: Groups, Sub-groups, Lagrange theorem, Normal subgroups, Quotient groups, Group actions, Homomorphisms, Group of symmetry - rigid motion group, finite subgroups of the rotation group, symmetric group. Metric Spaces: Open sets, Closed sets, Sequences, Continuity, Complete metric spaces, Contraction principle and applications, Connectedness and compactness. Fractals: Metric space of fractals and its completeness, Iterated function systems, Attractor, Algorithms to generate fractals. Topology of Surfaces: Euler's theorem, Construction of surfaces by identification: Torus, mobius strip, Klein bottle.

MTH 301 **ANALYSIS-I** **Prereq. MTH 101 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Real number system and set theory : Completeness property, Archimedian property, Denseness of rationals and irrationals, Countable and uncountable, Cardinality, Zorn's lemma, Axiom of choice. Metric spaces: Open sets, Closed sets, Continuous functions, Completeness, Cantor intersection theorem, Baire category theorem, Compactness, Totally boundedness, Finite intersection property. Functions of several variables: Differentiation, inverse and implicit function theorems. Rlemann-Stieitjes integral: Definition and existence of the integral, Properties of the integral, Differentiation and integration. Sequence and Series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. Equicontinuity, Ascoli's Theorem.

MTH 302 **MATHEMATICAL LOGIC** **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Formal theories, consequence and deduction. Classical Propositional Calculus: Syntax, truth, validity, Adequacy of connectives, normal forms, applications to circuit design, Axiomatic treatment, deduction theorem, derived rules of inference, Soundness, Independence of axioms, Consistency, completeness, Completeness w.r.t. Boolean algebras, Computer-assisted formal proofs: tableaux, resolution. Classical first order theories: Syntax, satisfaction, truth validity, Axiomatic treatment, Equality, Examples of first-order theories : Peano arithmetic, Groups, Orderings, Basis of axiomatic set theory, Deduction theorem, derived rules of inference, soundness, Consistency, completeness, Lowenheim-Skolem theorems, compactness, First-order theories with equality, Decidability, Computer-assisted formal proofs: tableaux, resolution. Godel's incompleteness theorems. Examples of other/non-classical logics. Other proof techniques-natural deduction, sequent calculus.

MTH 304 **TOPOLOGY** **Prereq. MTH 301**

L-T-P-D-[C]
3-1-0-0-[4]

Topological spaces, Basis for a topology, The order topology, Subspace topology, Closed sets. Countability axioms, Limit points, Convergence of nets in topological spaces, Continuous functions, The product topology, Metric topology, Quotient topology. Connected spaces, Connected sets in R, Components and path components, Compact spaces, Compactness in metric spaces, Local compactness, One point compactification. Separation axioms, Uryshon's lemma, Uryshon's metrization theorem, Tietz extension theorem. The Tychonoff theorem, Completely regular spaces, Stone -Czech compactification.

MTH 306 **LINEAR PROGRAMMING AND EXTENSIONS** **Prereq. MTH 201**

L-T-P-D-[C]
3-1-0-0-[4]

Linear Models: Formulation and Examples, Basic Polyhedral Theory- Convexity, Extreme points, Supporting hyperplanes etc, Simplex Algorithm- Algebraic and Geometrical approaches, Artificial variable technique, Duality Theory: Fundamental theorem, Dual simplex method, Primal-dual method, Sensitivity Analysis, Bounded Variable L.P.P. Transportation Problems: Models and Algorithms, Network Flows: Shortest path Problem, Max-Flow problem and Min-cost Flow problem, Dynamic Programming: Principle of optimality, Discrete and continuous models.

MTH 308 **PRINCIPLES OF NUMERICAL COMPUTATION** **Prereq. MTH 203**

L-T-P-D-[C]
3-1-0-0-[4]

Root find problem for transcendental and polynomial equations - methods and analysis. Interpolation: Lagrange, divided difference, finite difference, Hermite and Spline interpolation, Inverse interpolation. Approximation - Least squares and minimax approximation. Numerical differentiation. Numerical integration-Newton-Cotes and Gauss quadratures. Numerical methods (direct and iterative) for solving linear systems with error analysis. Eigen values and eigen vectors for linear algebraic systems. Numerical methods for initial value problems.

MTH-311 **PROBABILITY THEORY-I** **Prereq. ESO 209**

L-T-P-D-[C]
3-1-0-0-[4]

Sets and set operations, Sample space, Sigma fields, Measurable spaces, Events. Measure spaces, Caratheodory's extension theorem, Construction of measures, Product spaces, Product measures. Probability measurer and its properties. Independence of events. Measurable functions, Approximations through simple functions, Random variables. Induced measures and probability distribution functions: discrete, continuous and absolutely continuous, one to one correspondence with induced probability measure, decomposition. Independence of random variables, Borel-Cantelli lemmas. Integration in measure spaces, Expectation, Fatou's lemma, Monotone convergence and dominated convergence theorems, Uniform integrability, Markov, Chebyshev, Cauchy-Schwarz, Minkowski, Holder, Jensen and Lyapunov inequalities. Absolute continuity of measures, Randon-Nikodym theorem, Conditional expectation, Conditional probability measures. Fubini's theorem, Convolution. Functions of random variables, Jacobian theorem.

MTH 401 **THEORY OF COMPUTATION** **Prereq. ESO211 / MTH303 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Some fundamental proof techniques. Finite Automata: Finite automata and regular languages, Languages that are and are not regular, Algorithm aspects of finite automata. Context-free grammars: Push-down automata, Languages that are and are not context-free, Algorithms for context-free grammars. Basic Turing machine model and Turing computability: Variants of Turing machines. Grammars and Turing machines: Primitive recursive functions, μ-recursive functions and Turing computability. Church-Turing thesis and Universal Turing machines: Halting problem, Some undecidable problems. Time-bounded Turing machines: Classes P and NP, NP-completeness, Examples of NP-complete problems, The time hierarchy.

MTH 403 **COMPLEX ANALYSIS** **Prereq. MTH 301 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Spherical representation of extended complex plane, Analytic Functions, Harmonic Conjugates, Elementary Functions, Cauchy Theorem and Integral Formula, Homotopic version, Power Series, Analytic Continuation and Taylor's theorem, Zeros of Analytic functions, Hurwitz Theorem, Maximum Modulus Theorem and Open Mapping Theorem, Laurent's Theorem , Classification of singularities, Residue theorem and applications, Argument Principle, Theorems of Rouche and Gauss-Lucas, Mobius Transformations, Schwarz-Christoffel Transformation, Iterated Functions System, Fractals, Algorithms to generate Sierpinski Gasket.

MTH 404 **ANALYSIS-II** **Prereq. MTH 301 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Lebesgue measure on R^n : Introduction, outer measure, measurable sets, Lebesgue measure, regularity properties, a non-measurable set, measurable functions, Egoroff's theorem, Lusin's theorem. Lebesgue integration: Simple functions, Lebesgue integral of a bounded function 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, absolutely continuity, L^p-spaces: The Minkowski's inequality and Hölder's inequality, completeness of L^p, denseness results in L^p. Fourier series: Definition of Fourier series, formulation of convergence problems, The L^2 theory of Fourier series, convergence of Fourier series.

MTH 405 **FUNCTIONAL ANALYSIS** **Prereq. MTH 301 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Fundamentals of normed linear spaces: Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Bounded linear maps on a normed linear spaces: Examples, linear map on finite dimensional spaces, finite dimensional spaces are isomorphic, operator norm. Hahn-Banach theorems: Geometric and extension forms and their applications. Three main theorems on Banach spaces: Uniform boundedness principle, divergence of Fourier series, closed graph theorem, projection, open mapping theorem, comparable norms. Dual spaces and adjoint of an operator: Duals of classical spaces, weak and weak* convergence, Banach Alaoglu theorem, adjoint of an operator. Hilbert spaces : Inner product spaces, orthonormal set, Gram-Schmidt ortho-normalization, Bessel's inequality, Orthonormal basis, Separable Hilbert spaces. Projection and Riesz representation theorem: Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem. Bounded operators on Hilbert spaces: Adjoint, normal, unitary, self adjoint operators, compact operators, eigen values, eigen vectors, Banach algebras. Spectral theorem: Spectral theorem for compact self adjoint operators, statement of spectral theorem for bounded self adjoint operators.

MTH 406 **DISTRIBUTION THEORY AND FOURIER TRANSFORMS**

Prereq. MTH 304, MTH 405 #

L-T-P-D-[C]
3-1-0-0-[4]

Introduction, Test function spaces, Calculus with distributions, supports of distributions, Structure theorems, convolutions, Fourier transforms, L^1 L^2 theory of Fourier Transform, Tempered distributions, Paley-Wiener theorem, weiner-Tauberian theorem, Applications of distributions theory and Fourier transform to differential equations.

MTH 407 **CALCULUS OF VARIATIONS AND INTEGRAL EQUATIONS**

L-T-P-D-[C] **Prereq. MTH 203 #**

3-1-0-0-[4]

Euler's equation and its generalization; Variational problems with moving boundaries; Rayleigh-Ritz method. Classification of integral equations, Neumann's iterative method for Fredholm's equation of 2nd kind; Volterra type integral equations; Integral equations of first kind.

MTH 409 **COMPUTER PROGRAMMING AND DATA STRUCTURES** **Prereq. #**

L-T-P-D-[C]

3-1-0-0-[4]

Fortran 77: Integer and real operations, logic and complex operations, Control statements, Do statement, arrays subroutines and functions. Introduction to data structures in C Programming Language; Arrays: linear, Multi-dimensional, Records, Pointers, Stacks, queues, Linked Lists; Singly linked lists, doubleed linked lists, circular linked lists, Application of Linked Lists; Polynomial addition, sparse matrices, Trees: binary trees, red-black trees, Hash tables. some discussion about data structures in F90-F95 with examples.

MTH 411 **PROBABILITY THEORY-II** **Prereq. MTH 311 / #**

L-T-P-D-[C]

3-1-0-0-[4]

Tight families of probability distributions, Convergence of probability distribution functions, Helly's theorem, Helly-Bray theorem, Skorohod's fundamental theorem, Scheffe's theorem; Weak convergence, Uniform integrability and convergence of expectations. Characteristic functions, Inversion formula, Levy continuity theorem, Expansion of characteristic functions, Polya's theorem, Bochner's theorem. Moments and uniqueness of the probability distribution, Frechet-Shohat theorem. Central limit theorems: Lindeberg-Levy, Lyapunov and Lindeberg-Feller. Various modes of convergence and the interrelations. Strong and weak laws of large numbers.

MTH 412 **STOCHASTIC PROCESSES** **Prereq. MTH-311 / #**

L-T-P-D-[C]

2-0-3-0-[4]

Definition and classification of general stochastic processes. Markov Chains: definition, transition probability matrices, classification of states, limiting properties. Markov Chains with Discrete State Space: Poisson process, birth and death processes. Renewal Process: renewal equation, mean renewal time, stopping time. Markov Process with Continuous State Space: Introduction to Brownian motion.

MTH 413 **REAL AND COMPLEX ANALYSIS** **Prereq. #**

L-T-P-D-[C]

3-1-0-0-[4]

Real and complex numbers; Open, closed and compact sets in R^n ; Limits and continuity; Differentiation and Integration; Sequences and series; Sequences and series of functions; Complex integration.

MTH 415 **MATRIX THEORY AND LINEAR ESTIMATION** **Prereq. ESO 209, #**

L-T-P-D-[C]
3-1-0-0-[4]

Review of finite dimensional vector spaces (Null space and nullity), Linear dependence and independence, Matrix algebra, Rank of a Matrix, Inverse of a non-singular matrix. Hermite canonical forms, Generalised inverses, Moore-Penrose inverse, solution of linear equations, Projection and orthogonal projection matrices, Idempotent matrices. Real quadratic forms, reduction of pair of real symmetric matrices, Singular value decomposition. extrema of a quadratic forms, Vector and matrix differentiation. Least squares theory and Gauss-Markoff theorem, Cochran's theorem and distribution of quadratic forms, test of single linear hypothesis and more than one hypothesis, ANOVA table, Confidence interval and regions, Power of F-test. Multiple comparisons and simultaneous confidence intervals.

MTH 416 **REGRESSION ANALYSIS** **Prereq. MTH 415, ESO 209, #**

L-T-P-D-[C]
3-1-0-0-[4]

Simple and multiple linear regression, Polynomial regression and orthogonal polynomials, Test of significance and confidence intervals for parameters. Residuals and their analysis for test of departure from the assumptions such as fitness of model, normality, homogeneity of variances, detection of outliers, Influential observations, Power transformation of dependent and independent variables. Problem of multicollinearity, ridge regression and principal component regression, subset selection of explanatory variables, Mallow's Cp statistic. Nonlinear regression, different methods for estimation (Least squares and Maximum likelihood), Asymptotic properties of estimators. Generalised Linear Models (GLIM), Analysis of binary and grouped data using logistic and log-linear models.

MTH 417 **SAMPLING THEORY** **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Principles of sample surveys; Simple, Stratified and unequal probability sampling with and without replacement; ratio, product and regression method of estimation; systematic sampling; cluster and subsampling with equal unequal sizes; double sampling; sources of errors in surveys.

MTH 418 **INFERENCE I** **Prereq. ESO 209, #**

L-T-P-D-[C]
3-1-0-0-[4]

Parametric models, parametrs, random sample and its likelihood, statistic and its sampling distributions, problems of inference. Examples from standard discrete and continuous models such as Bernoulli, Binomial, Poisson, Negative Binomial, Normal, Exponential, Gamma, Weibull, Pareto etc. Concept of sufficiency, minimal sufficiency, Neyman factorization criterion, Fisher information, exponential families. Maximum likelihood estimators, method of moment estimators, percentile estimators, least squares estimators, minimum mean squares estimators, uniformly minimum variance unbiased estimators, Rao-

Blackwell theorem, Cramer-Rao lower bond, different examples. Statistical Hyptheses-simple and composite, statistical tests, critical regions, Type-I and Type-II errors, size and power of a test, Neyman Pearson lemma and its different applications. Most powerful test, uniformly most powerful test, unbiased test and uniformly most unbiased test. Likelihood ratio test. Interval estimation, confidence intervals, construction of confidence intervals, shortest expected length confidence interval, most accurate one sided confidence interval and its relation to UMP test.

MTH 421 **ORDINARY DIFFERENTIAL EQUATIONS** **Prereq. MTH-203 / #**
L-T-P-D-[C]
3-1-0-0-[4]

Vector Fields, Graphical representation of solutions, Lipschitz functions, Integral inequalities, Uniqueness of solutions, Boundary value problems, Green's functions, Distribution of zeros of solutions, Functional analytical preliminaries, Existence of solutions by Picard's method, Existence by Perron's method, Uniqueness and continuous dependence, Continuity and differentiability w.r.t., initial Conditions and parameters, Continuation of solutions, Linear equations, general theory, Solutions of linear equations with constant coefficients, Equations with periodic coefficients, Floquet's theory, Classification of stationary points and phase portraits, Oscillation and boundedness of solutions, Lyapunov theory of stability, Poincare Bendixon theorem and applications.

MTH 423 **INTRODUCTION TO CONTINUUM MECHANICS** **Prereq. MTH-203 / #**
L-T-P-D-[C]
3-1-0-0-[4]

Introduction to tensors. Stress tensor. Equilibrium equations. Mohr's circle for plane stress. Deformation, Strain tensor, Rate of deformation tensor. Equations of motion. Dynamic similarity. Exact solutions. Laminar boundary layer over a float plat. Vorticity circulation & irrational flow. Torsion of cylindrical bars, Plane elastic waves.

MTH 424 **PARTIAL DIFFERENTIAL EQUATIONS** **Prereq. MTH-421 / #**
L-T-P-D-[C]
3-1-0-0-[4]

Mathematical models leading equations. First order quasi-linear equations. Nonlinear equations. Cauchy-Kowalewski's theorem. Higher order equations and characteristics. Classification of second order equations. Riemann's method and applications. One dimensional wave equation and De'Alembert's method. Solution of three dimensional wave equation. Method of decent and Duhamel's principle. Solutions of equations in bounded domains and uniqueness of solutions. BVPs for Laplace's and Poisson's equations. Maximum principle and applications. Green's functions and properties. Existence theorem by Perron's method. Heat equation, Maximum principle. Uniqueness of solutions via energy method. Uniqueness of solutions of IVPs for heat conduction equation. Green's function for heat equation. Finite difference method for the existence and computation of solution of heat conduction equation.

MTH 428 | **MATHEMATICAL METHODS** | **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Multiple Integral Theorems and their Applications: Green's theorem, Stoke's theorem and Gauss divergence theorem. Integral Transforms: Fourier, Fourier sine/cosine and Hankel Transforms with their inverse transforms (properties, convolution theorem and application to solve differential equation). Perturbation Methods: Perturbation theory, Regular perturbation theory, Singular perturbation theory, Asymptotic matching. Calculus of Variation: Introduction, Variational problem with functionals containing first order derivatives and Euler equations. Functionals containing higher order derivatives and several independent variables. Variational problem with moving boundaries. Boundaries with constraints. Higher order necessary conditions, Weiretrass function, Legendre's and Jacobi's condition. Existence of solutions of variational problems. Rayleigh-Ritz method, statement of Ekeland's variational principle; Self adjoint, normal and unitary operators; Banach algebras.

MTH 488 | **TOPICS IN PROBABILITY AND STOCHASTIC PROCESSES** | **Prereq. MTH 411, #**

L-T-P-D-[C]
3-1-0-0-[4]

Conditional probabilities and conditional expectations with respect to a algebra, Construction of a process with a given finite dimensional distribution, The Hilbert space L^2, Gaussian systems, Markov processes with continuous state space, Renewal theory, Stationary processes and Ergodic theory, Martingales, Branching processes.

MTH 506 | **OPTIMIZATION** | **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

Optimization Problem: various examples, Characterization of optimality and constrained optimal problems, Convex sets and convex functions and their properties, Non-linear programming theory - Kuhn-Tucker conditions, Lagrange's theory, Duality theory, Search techniques - one variable and several variables, Pontryagin's maximum principle and its applications, Dynamic programming and its applications.

MTH 511 | **STATISTICAL SIMULATION AND DATA ANALYSIS** | **Prereq. ESO-209 / #**

L-T-P-D-[C]
3-1-0-0-[4]

Simulation of random variables from discrete, continuous, multivariate distributions and stochastic processes, Monte-Carlo methods. Regression analysis, scatter plot, residual analysis. Computer Intensive Infer-ence Methods - Jack-Knife, Bootstrap, cross validation, Monte Carlo methods and permutation tests. Graphical representation of multivariate data, Cluster analysis, Principal component analysis for dimension reduction.

MTH 512 L-T-P-D-[C] 3-1-0-0-[4]

FOUNDATIONS OF MATHMATICAL FINANCE **Prereq. ESO-209 / #**

Fundamentals of the financial markets, meaning of notions like asset portfolio derivatives (example : Futures, options forwwards etc.)

Binomial asset pricing model under no arbitrage condition single-period model, multi-period model. risk-neutral probabilities, martingales in the discreate framework, risk-neutral valuation of European and American ooptions under no arbitrage condition in the binomial framework.

Introduction to continuous time models. Basic notions of probability theory on an infinite sample space. Change of measure and the Radon-Nikodym derivative. Random walk and Brownian motion, Ito intergral and Ito formula Black-Scholes formula for pricing an European call option.

Markowitz mean-variance portfolio optimization problem. Single-period and multi- period model, Capital asset pricing model, outlines of the measures of risk, Value- at - Risk (VaR) and Conditional - Value- at - Risk (CVaR)

MTH 513 L-T-P-D-[C] 3-1-0-0-[4]

ANALYSIS OF VARIANCE **Prereq. MTH 416**

Analysis of completely randomized design, randomized block design, Latin squares design; Splitplot, 2" and 3" factorials with total and partial confounding, two-way non-orthogonal experiment, BIBD, PBIBD; Analysis of covariance, missing plot techniques; First and second order response surface designs.

MTH 514 L-T-P-D-[C] 3-1-0-0-[4]

MULTIVARIATE ANALYSIS **Prereq. MTH 418**

Multivariate normal distribution, assessing normality, Wishart and Hotelling's T^2; Comparisons of several multivariate means, MANOVA; multivariate linear regression models; principal components, factor analysis; canonical correlations; discrimination & classification.

MTH 515 L-T-P-D-[C] 3-1-0-0-[4]

INFERENCE II **Prereq. MTH 418**

Group families, the principle of equivariance, location family, scale family, location scale family. Minimum risk equivariance estimators, risk functions, admissibility, prior distribution, posterior distribution, geometric interpretation for finite parameter space, Bayes estimators, limit of Bayes estimators, minimax estimators and their relations. Review of convergence in probability and convergence in distributions. Consistency results of the mle's, and the mme's. Asymptotic relative efficiency. Consistent and Asymptotic Normal (CAN) estimators, Invariance of CAN estimators under different transformations. CAN estimators obtained by moments and MLE methods in one parameter xponential family and multiparameter exponential family. Sequential Probability Ratio Tests and its applications in different practical problems. Invariant test and unbiased tests, Likelihood ratio test and its asymptotic distributions, Wald test, Rao's score test, Pearson c^2 test for goodness of fit. Large sample tests and confidence intervals based on CAN estimators. Consistency of large sample tests and asymptotic powers of large sample tests.

MTH-516 **NON-PARAMETRIC INFERENCE** **Prereq. ESO 209, #**

L-T-P-D-[C]

3-1-0-0-[4]

Order statistics, Run tests, Goodness of fit tests, rank order statistics, sign test and signed rank test. general two-sample problems, Mann-Whitney test, Linear rank tests for location and scale problem, k-sample problem, Measures of association, Power and asymptotic relative efficiency, Concepts of jackknifing, Bootstrap methods.

MTH-517 **TIME SERIES ANALYSIS** **Prereq. #**

L-T-P-D-[C]

3-1-0-0-[4]

Linear stationary processes, AR, MA, ARMA and ARIMA; identification, estimation of the models; forecasting time series regression; Fourier analysis, spectral representation of a stochastic process, properties of ARMA processes in the frequency domain; estimation of the spectrum, Kalman filter.

MTH 520 **NUMERICAL LINEAR ALGEBRA** **Prereq. MTH102/ #**

L-T-P-D-[C]

3-1-0-0-[4]

Computer arithmetic. Vector and matrix norms. Condition number of a matrix and its applications. Singular value decomposition of a matrix and its applications. Linear least-squares problem. Householder matrices and their applications. Numerical methods for matrix eigenvalue problem. Numerical methods for systems and control.

MTH 522 **FINITE ELEMENT METHOD** **Prereq.:#**

L-T-P-D-[C]

3-1-0-0-[4]

Introduction and motivation, Weak formulation of BVP and Galerkin approximation, Piecewise polynomial spaces and finite element method, Computer implementation of FEM, Results from Sobolev spaces, Variational formulation of elliptic BVP, Lax-Milgram theorem, Estimation for general FE approximation, Construction of FE spaces, Polynomial approximation theory in Sobolev spaces, Variational problem for second order elliptic operators and approximations, Mixed methods, Iterative techniques.

MTH 523 **FLUID MECHANICS** **Prereq. #**

L-T-P-D-[C]

3-1-0-0-[4]

Review and General Properties of Navier Stokes Equations; Some Exact solutions of NS equations; Introduction to boundary layer theory; Introduction to turbulent flow; Introduction to compressible flow; Applications.

MTH 524 **ALGORITHMS** **Prereq. #**

L-T-P-D-[C]

3-1-0-0-[4]

Preliminaries: Introduction to algorithms; Analyzing algorithms: space and time complexity; growth of functions; summations; recurrences; sets, etc. Greedy Algorithms: General characteris-tics; Graphs: minimum spanning tree; The knapsack problem; scheduling. Divide and Conquer: Binary search; Sorting: sorting by merging, qucksort. Dynamic Programming: Elements of dynamic programming; The principle of optimality; The knapsack problem; Shortest paths; Chained matrix multiplication. Graph Algorithms: Depth-first search; Breadth-first search; Backtracking; Branch-and-bound. Polynomials and FFT: Representa-tion of polynomials; The DFT and FFT; Efficient FFT implementation. Number Theoretic Algorithms: Greatest common divisor; Modular arithmetic; Solving modular linear equations. Introduction to cryptography. Computational Geometry: Line segment properties; Intersection of any pair of segments; Finding the convex hull; Finding the closest pair of points. Heuristic and Approximate Algorithms: Heuristic algorithms; Approximate algorithms; NP-hard approximation problems.

MTH 531 **ALGEBRAIC TOPOLOGY** **Prereq. MTH 330 #**

L-T-P-D-[C]

3-1-0-0-[4]

Homotopy of paths; The fundamental group, Covering spaces. Simplicial complexes and simplicial maps; Homology groups; Barycentric subdivision; The simplicial approximation theorem. Singular homology groups; The exact homology sequence; The Eilenberg-Steenrod axioms, Mayer-Vietoris sequence.

MTH 598 / **Project I** L-T-P-D-[C] **Prereq. #**

MTH 599 **Project I** 0-0-0-7-[4] For both course

MTH 600 **SET THEORY AND LOGIC** **Prereq. #**

L-T-P-D-[C]

3-0-0-0-[4]

Propositional calculus, Set theoretic concepts; Truth on algebraic systems; The calculus of predicates; Model theory; Proof Theory; Algorithms and recursive functions.

MTH 601 **MATHEMATICS OF COMPUTERIZED TOMOGRAPHY** **Prereq. #**

L-T-P-D-[C]

3-0-0-0-[4]

Elements of digital image processing. Fourier, Random & related trans-forms.Projection theorem. Helgason-Ludwig consistency theorem. Sampling, resolution, ill-posedness, regularization and accuracy. Limited data problems. SVD, Tikhonov Phillips,CBP, FT, ART, EM, MENT, CSI etc. methods.

MTH 603 **MATHEMATICAL MODELLING** **Prereq. #**

L-T-P-D-[C]

3-0-0-0-[4]

Elementary mathematical models; Role of mathematics in problem solving;

Concepts of mathematical modelling; System approach; formulation, Analyses of models; Sensitivity analysis, Simulation approach; Pitfalls in modelling, Illustrations.

MTH 606 **BIOMATHEMATICS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Biofluid dynamics; Blood flow & arterial diseases; Transport in intestines & lungs; Diffusion processes in human systems; Mathematical study of nonlinear Volterra equations, Stochastic & deterministic models in population dynamics and epidemics.

MTH 608 **MODEL THEORY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Some first order logic-completeness, compactness and Skolem-Lowenheim theorems, Theories, Models of theories, Elementary extensions and chains, Skolem functions and indiscernibles, Elementary embeddings and equivalence, Algebraic charecterization of elementary equivalence, Ehrenfeucht games, Finite axiomatizability, Lindstrom's characterization theorems, Ultraproducts, Lindenbaum algebras, Ultrafilters, Rasiowa-Sikorski construction. Free models, Basics of logic programming.

MTH 609 **PROOF THEORY AND AUTOMATED DEDUCTION** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Classical Propositional Logic - Deduction Systems, Automatic Methods; Non - classi cal Propositional Logic - Intutionistic Logic, Normalization, Cut Elimination; Curry-Howard Correspondence; First Order Logic-Deduction Systems; Resolution; Tableaux Methods; Equality and Equational Logics; Type theory; Formalized Number Theory; Godel's Incompleteness Theorems.

MTH 610 **APPLIED MATRIX THEORY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Review of basic lin.alg. canonical factorization. Q-Forms. Courant- Fischer minmax & related theorems. Perron-Frobenius theory. Matrix-stability. Inequalities, g-inverse (A^-, A_m, A^+). Direct, iterative, projection and rotations methods for solving linear systems & eigenvalues problems. Applications.

MTH 611 **ALGEBRA-II** **Prereq. MTH-204 / #**

L-T-P-D-[C]
3-0-0-0-[4]

Fields: definition and examples. Ring of polynomials over a field. Field extensions. Algebraic and transcendental elements, Algebraic extensions. Splitting field of a polynomial. Algebraic closure of a field, Uniqueness. Normal, separable, purely inseparable extensions. Primitive elements of a field extension - simple extensions. Fundamental theorem of Galois. Solvability by radicals - Solutions of cubic and quartic polynomials, Insolvabity of quintic and higher degree polynomials. Geometric construct-ions. Cyclotomic extensions. Finite fields.

Cyclotomic polynomials and its properties. Traces and norms. Modules - definition, examples and basic properties. Free modules, submodules and quotient modules, isomorphism theorems. Localization. Direct sum and direct products. Noetherian and Artinian rings and modules, structure of Artinian rings, Hilbert basis theorem. Jordan - Holder theorem. Radicals of modules, Nakayama lemma.

MTH 612 **AN INTRODUCTION TO COMMUTATIVE ALGEBRA** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Commutative rings, ideals, prime and maximal ideals, Noetherian Artinian rings, Primary decomposition and Noetherian rings, Modules over commutative rings, Exact sequences, the Hom and tensorufunctors, rings and modules of fractions, integral dependence, valuations and dedekind domains.

MTH 613 **RINGS AND MODULES** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Modules, Free modules, Cartesian products and direct sums of modules. Split exact sequences, Projective modules, Injective modules. Structure modules and rings, Artinian and Noetherian modules, Simple and semi simple modules, Radicals of rings and modules, Special rings and modules.

MTH 614 **MATHEMATICAL CODING THEORY-I** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Polynomial rings over fields, Extension of fields, computation in GF(q), Root fields of polynomials, Vector spaceover finite fields, Binary group codes, Hamming codes, Polynomial codes, Linear block codes, The structure of cyclic codes. Quadratic residue codes, Reed Mueller codes, Simplex codes.

MTH 616 **ANALYTIC NUMBER THEORY** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Averages of mathematical functions. Distri-bution of primes, Weyl's, Kronecker's and Minkowski's theorems. Characters. Dirichlet's theorem on primes in arithmetic progression. Gauss sums. Dirichlet series and Euler products. Analytic proof of the prime number theorem.

MTH 617 **ALGEBRAIC NUMBER THEORY** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Congruences with prime modulus, P-adic equations & padic fields, Hasses Minkowski theorem, Hilbert-symbol, Algebraic number fields, Unique factorization, Cyclotomic integers, Characters of finite abelian groups, Dirichlet series, Dirichlet's theorem on prime numbers in A.P. & class number.

MTH 618 **FINITE FIELD AND ITS APPLICATIONS** **Prereq. MTH 204 #**

L-T-P-D-[C]
3-0-0-0-[4]

Introduction, Structure of finite fields, Polynomials over finite fields, Factorization of polynomials, Construction of irreducible polynomials, Applications in cryptography and coding theory.

MTH 619 **COMMUTATIVE ALGEBRA II** **Prereq. MTH 612**

L-T-P-D-[C]
3-0-0-0-[4]

Completions, Diemension theory, Cohen-Macaulay rings, Regular local rings, Projective and injective modules and resolutions, Homological methods.

MTH 620 **MEASURE THEORY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Algebras and s-algebras, Measures, Outer measures, Lebesgue measure in R^n, Completeness and regularity. Measurable functions and their properties, Convergence in measure, Integral, Convergence theorems. Signed and complex measures, Radon Nikodym theorem, Lebesgue decompostion theorem, L^p-spaces and their dual. Product measures, Construction, Fubini theorem and its applications, Differentiation of measures.

MTH 621 **FOURIER ANALYSIS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Fourier series; Norm and pointwise convergence, Approximate identities, Plancherel theorem, Conjugation, Maximal functions, Classical Hardy spaces, F. and M. Riesz theorem, Interpolation of linear operators. Fourier & Fourier Stieltjes transforms, Tempered distributions, Paley-Wiener theorems. Wiener-Tauberian theorems & applications.

MTH 623 **TOPOLOGY OF RIEMANNIAN MANIFOLDS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

First & second variation of arc length, Conjugate points, Myers & Bonnet theorem, Rauch comparison theorems, Cartan-Hadamard theorem, Cartan-Abrose-Hicks theorem, Spaces of constant curvature; Morse theory; Application to the path space of a manifold.

MTH 624 **DIFFERENTIABLE MANIFOLDS AND LIE GROUPS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Differentiable manifolds; Tangent space. Vector fields; Frobenius theorem; Relation between Lie sub-algebras & Lie subgroups; Cartan's theorem on closed subgroups; One parameter subgroups; Exponential maps; Adjoint representation; Homogeneous spaces; Compact Lie groups; Symmetric spaces.

MTH 625 **NON-LINEAR ANALYSIS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Calculus in Banach spaces, Inverse & implicit function theorem, Fixed point theorems of Brouwer, Schauder & Tychonoff; Fixed point theorems for nonexpansive & set-valued maps; Predegree results, Compact vector fields, Homotopy, Homotopy extension & invariance theorems & applications.

MTH 626 | **TOPICS IN ANALYSIS** | **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Review of basic theorems on Banach spaces, Locally convex spaces, Convexity, Hahn Banach separation theorems, Extreme points, Krein-Milman theorem, Theory of distributions, Tempered distributions, Interpolation of operators, Weak type inequalities, Applications, Compact operators, Integral operators, Fredholm alternative.

MTH 627 | **APPLIED HARMONIC ANALYSIS**

L-T-P-D-[C]
3-0-0-0-[4]

Basic Fourier Analysis-a review Convolutions, Multipliers and Filters, Poisson Summation Formula, Shannon Sampling Discrete Fourier Transform, Fast Fourier Transform, Discrete Wavelets, Continuous Wavelets, Uncertainty Principles, Radar Ambiguity, Phase Retrieval, Random Transform, Basic Properties, Convolution and Inversion, Computerized Tomography

MTH 628 | **TOPICS IN TOPOLOGY** | **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Classification of 2-dimensional surfaces; Fundamental group; Knots and covering spaces; Braids and links; Simplicial homology groups and applications; Degree and Lefschetz Number; Borsuk-Ulam Theorem; Lefschetz Fixed-Point Theorem.

MTH 629 | **BANACH SPACES OF VECTOR VALUED FUNCTIONS** | **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Banach spaces containing copies of c_α l_1 or l_∞ The spaces L_∞ (μ, X), $C(K, X)$ and their duals. Copies of c_α, l_1 or l_∞ in L_π (μ, X), and $C(K, X)$, Complemented copies of c_α, l_1 or l_∞ in $L_\pi(\mu, X)$, $C(K, X)$ complemented copies of c_α and l_1 or l_∞ in L_∞ (μ, X).

MTH 630 | **FUNCTIONAL ANALYSIS** | **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Completion of metric spaces, Banach fixed point theorem, Baire category theorem, Banach spaces, Conjugate spaces, Reflexivity, Open mapping & closed graph theorems, The principle of uniform boundedness, Hilbert spaces, Riesz representation theorem, Banach algebras, Gelfand Naimark theorem; Spectral decomposition for compact normal operators.

MTH 631 | **APPROXIMATION THEORY** | **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Best approximation in normed spaces. Tchebycheff systems. Tchebycheff-Weierstrass - Jackson - Bernstein - Zygmund-Nikolaev etc. theorems. Fourier series, Splines, Convolutions, Linear positive, Variation diminishing, Simultaneous etc. approximations. Direct-inverse-saturation theorems. Applications.

MTH 632 **VECTOR MEASURES** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

General vector measure theory, Integration, Analytic Radon Nikodym theorems and operators on L (μ), Martingales, Geometric aspects of the Radon-Nikodym property.

MTH 633 **APPLIED FUNCTIONAL ANALYSIS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Hahn Banach theorem, Open mapping theorem, Uniform boundedness principle; Applications. Weak and weak-star topologies, Mazur's, Alaoglu's, and Goldstine theorems, Reflexive spaces, James characterization of reflexivity. Fixed point theorems of Brouwer, Schauder and Tychonoff; Applications.

MTH 634 **BASES IN LOCALLY CONVEX SPACES AND KOETHE SEQUENCE SPACES,** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Preliminaries, Elements of basis theory, Types of bases, Summability (summation of infinite series), Koethe sequence spaces, Bases in OTVS, Isomorphism theorems.

MTH 635 **WAVELETS AND APPLICATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Fourier transforms, Wavelets transforms and time-frequency analysis, Cardinal spline analysis, Scaling functions and wavelets, Cardinal spline wavelets, Orthogonal bases of compactly supported wavelets, Applications to signal analysis.

MTH 636 **GEOMETRY OF NORMED LINEAR SPACES** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Geometric form of Hahn-Banach theorem, w-w^* topologies, James characterization of reflexivity, Strict convexity, Uniform convexity, Duality between strict convexity and smoothness, Differentiability of the norm, Drop theorem, Bishop-Phelp theorems, Krein-Milman theorem and Radon-Nikodym property.

MTH 637 **TOPICS IN OPERATOR THEORY AND HARMONIC ANALYSIS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Operators on Hilbert spaces: Compact operators, Schatten class and Hilbert Schmidt operators, Spectral theorem. Fourier series, Smooth functions and distributions. Hardy spaces, Carleson measures, H^1-BMO duality. Hankel and Toeplitz operators on H^2. Representation theory of compact groups, Representation of SU(2) and SO(3).

MTH 638 L-T-P-D-[C] 3-0-0-0-[4]

ABSTRACT HARMONIC ANALYSIS **Prereq. #**

Integration on locally compact spaces, Topological groups, Haar measure, Fourier transforms, Bochner theorem, Pontryagin's duality theorem, Plancherel theorem, Bohr compactification.

MTH 639 L-T-P-D-[C] 3-0-0-0-[4]

LOCALLY CONVEX SPACE **Prereq. #**

Topological linear spaces, Equicontinuity, Function spaces, Convexity & convex topological spaces, Hahn-Banach theorem, Barrelled spaces, Principle of uniform boundedness, Bornological spaces, Duality theory (Aren's Th., Mackey topology, S-topology, Polarity).

MTH 640 L-T-P-D-[C] 3-0-0-0-[4]

SEVERAL COMPLEX VARIABLES **Prereq. #**

Cauchy integral formula, Taylor series, Associated radii of convergence, Analytic functions, Reinhardt domain, Logarithmic convexity, Laurent's expansion, Envelope of holomorphy, Goldberg's growth parameter, Factorization, Weirestrass preparation theorem, Types of singularity, Domain of holomorphy, Complex analytic structure.

MTH 641 L-T-P-D-[C] 3-0-0-0-[4]

COMPUTATIONAL COMPLEX ANALYSIS **Prereq. #**

Formal power series, Quotient-difference algorithm, Algorithms for determination of zeros of entire functions and residues of rational functions, Horner's algorithm. Continued fractions, Pade' approximation and applications, Complex variable boundary element method & engineering applications.

MTH 642 L-T-P-D-[C] 3-0-0-0-[4]

GEOMETRIC FUNCTION THEORY **Prereq. #**

Normal families & applications, Riemann mapping theorem, Conformal mapping of a sequence of domains; Modular function, Hyperbolic metric, Elementary theory of univalent functions, Löwner's theory, Dirichlet problem,Green's function & conformal mapping; Transfinite diameter & capacity; Symmetrization, Extremal length and prime ends.

MTH 643 L-T-P-D-[C] 3-0-0-0-[4]

COMPLEX APPROXIMATION **Prereq. #**

Faber series. Polynomial approximation in L^p-norm and supnorm. Theorems of Weierstrass, Bernstein & Walsh. Approximation on general compact sets. Theorems of Runge, Mergelyan etc, Approximation by interpolation, Complex planar splines. Complex spline approximation.

MTH 644 **COMPLEX FUNCTION THEORY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Fundamental theorems, Winding number & applications,Normal families, Riemann mapping theorem, Fundamentals of univalent functions & entire functions, Phragmen-Lindelöf theorems, Gamma-, Riemann-zeta functions; Harmonic functions,Dirichlet problem for disc, Analytical continuation, Runge's theorem.

MTH 645 **ENTIRE AND MEROMORPHIC FUNCTIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Maximum modulus, Maximum term and rank, Order and lower order, Type and lower type, Rate of growth & distribution of zeros, Hadamard's factorization theorem & its implications, Minimum modulus, Proximate order and proximate type, Entire functions of exponential type, Nevanlinna theory.

MTH 646 **UNIVALENT AND MULTIVALENT FUNCTIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Area principle, Distortion theorems, Coefficient estimates, Bieberbach-Branges theorem, Variational methods, Extremal problems, Rotation theorems, Radii of starlikeness and convexity, Principle of subordination, p-valent, Mean p-valent and circumferencially mean p-valent functions.

MTH 647 **COMPLEX ANALYTIC DYNAMICS AND FRACTALS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Chordal & spherical metrics, Normal families. Iteration of polynomials and rational functions, Periodic points & orbits, Julia & Fatou's sets and their characterizations, Dynamics of Julia and Fatou's sets for quadratic, Rational & entire functions; The Mandelbrot set. Julia sets & fractals, Self-similarity and fractal dimension.

MTH 648 **DIFFERENTIAL GEOMETRY** **Prereq. MTH-301 / #**

L-T-P-D-[C]
3-0-0-0-[4]

Theory of Space Curves-The Serret-Frenet formulas. Gauss Theory of Surfaces-First and second fundamental form, Examples, Weingarten map, Principal curvatures, Gaussian curvature, Examples. Computation of the curvature in standard spaces: Sphere, Torus, Surfaces of revolution etc. Levi-Civita connection-Uniqueness, Gauss theorem Egregium, Hilbert's theorem on the positivity of curvature at a point on a compact surface in R^3. Geodesics, Equations of geodesics, Examples. Jacobi fields, Conjugate points etc. Riemannian area element on a surface, Gauss Bonnet theorem. Differentiable manifold, Differentiable structure. Sub-manifolds, Immersions, Embeddings. Metric tensor, Riemannian connection and curvature.

MTH 649 **ALGEBRAIC TOPOLOGY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Homotopy, Path homotopy. The fundamental group. Covering spaces. The fundamental group of the circle, S1, sphere, S2, Surfaces 2-dimensional, Punctured plane etc. Techniques of calculation. The special Van Kampen theorem. Essential and Inessential maps - Applications. The fundamental theorem of algebra, Brower's fixed point theorem for the disc etc. Triangulations. Simplical complexes. Barycentric subdivision. Simplical mappings, The simplical approximation theorem. Simplical homology groups; Calculations for cone complex, S^n etc. The Euler-Poincare formula. The Lefschetz fixed point theorem. Singular homology groups, Topological invariance. The exact homology sequence. The Eilenberg Steenrod axioms.

MTH 650 **PARTIAL DIFFERENTIAL EQUATIONS & THEIR APPLICATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

First order equations, Cauchy Kowalewski theorem. Characteristics. Classification of second order equations. Uniqueness theorems for hyperbolic equations with initial & boundary conditions, Elliptic equations, Dirichlet & Neumann problems. Maximum and minimum theorem, Poisson's integral, Green's & Neumann's functions. Heat equations.

MTH 651 **PARTIAL DIFFERENTIAL EQUATIONS OF PARABOLIC TYPE** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Maximum principle, Function spaces and imbedding theorems, Some inequalities, Weak solution, Energy inequality, Uniqueness theorem, Solvability of boundary value problems, Estimates in different functional norms, Regularity of the solutions.

MTH 652 **BOUNDARY VALUE PROBLEMS IN PARTIAL DIFFERENTIAL EQUATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Distributions & fundamental solutions; Fredholm alternative; Interior problem for elliptic equations; Surface layers & Green's function; Eigenvalue problems, Variational principle; Parabolic equations, Uniqueness & continuous dependence; Causal Green's functions; Wave equation & energy principle.

MTH 653 **INTEGRAL EQUATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Volterra and Fredholm integral equations, Resolvent Kernels. Operator equations, Fredholm theory, Hilbert-Schmidt theory. Nonlinear integral equations, Singular integral equations.

MTH 654 **ELLIPTIC EQUATIONS** **Prereq. #**

L-T-P-D-[C]
3-1-0-0-[4]

$W^{m,p}$ space, Imbedding & Trace theorems, Compactness of imbeddings, Green's formula, Weak formulation, Continuous dependence of solutions, Elliptic systems, Regularity in the interior, in a neighbourhood of a boundary. Existence of solution of BVP. Applications of Rellich's inequality.

MTH 655 **INITIAL BOUNDARY VALUE PROBLEMS - THEORY & APPLICATIONS TO HYPERBOLIC PROBLEMS** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Energy estimates for symmetric hyperbolic systems, Maximal dissipative boundary conditions, Kreiss theory for well posedness of hyperbolic initial boundary value problems, A prior energy estimates and differentiability results, Application of theory to radiative boundary conditions.

MTH 656 **SOBOLEV SPACES AND APPLICATIONS** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Elements of operator theory and Hilbert spaces; Introduction to the theory of distributions. Sobolev Spaces : Imbedding and compactness theorems, Fractional spaces and elements of trace theory. Applications to elliptic equations or parabolic equations.

MTH 657 **GRAPH THEORY** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Basic definitions. Blocks. Ramsey Numbers. Degree sequences. Connectivity. Eulerian and Hamiltonian Graphs. Planar graphs and 5-colour theorem. Chromatic numbers. Enumeration. Max-Flow Min-Cut Theorem. Groups and graphs. Matrices and graphs. Matchings and Hall's Marriage Theorem. Eigen values of graphs.

MTH 658 **NONLINEAR DYNAMICAL SYSTEMS** **Prereq. 421, #**
L-T-P-D-[C]
3-0-0-0-[4]

Picard's theorem, Boundedness of solutions, Omega limit points of bounded trajectories.LaSalle's invariance principle; Stability via Lyapanov's indirect method, Converse Lyapanov functions, Sublevel sets of Lyapanov functions, Stability via Lyapanov's direct method, Converse Lyapanov's theorems, Brokett's theorem, Applications to control system; Stable and unstable manifolds of equilibria, Stable manifold theorem, Hartman-Grobman theorem, Examples and applications, Center manifold theorem, Center manifold theorem, Normal form theory, Examples and applications to nonlinear systems and control; Poincare map, and stability theorems for periodic orbits; Elementary Bifurcation theory.

MTH 659 **ADVANCED QUANTITATIVE FINANCE** **Prereq. MTH 512**
L-T-P-D-[C]
3-0-0-0-[4]

Stochastic Voltality Models, Local Volatility, Short- Term Interest Rate Models, Health-Jarrow-Morton Framework, Options on Bonds, Options on Coupon- Bearing Bonds, LIBOR models, forward and Future LIBOR Rates, Valuation of Cap and floor, Interest Rate Swaps, Valuation of Swapation. Option pricing under jumps, overview of princing in incomplete matkets, basic notions of credit-risk modelling.

MTH660 **NOLOCAL INITIAL AND BOUNDARY VALUE PROBLEMS**
L-T-P-D-[C] **Prereq. MTH 421, 424**
3-0-0-0-[4]

Introducing of nonlocal initial and boundary value problems, types of nonlocal initial conditions, types of nonlocal boundary conditions, multi-point conditions, for heat and wave equations and their interpretations, functional analytic approach to solving such problems, formulation of the problems in a Hilbert/ Banach space, well-posendess of the models in the sense of Hadamard, semigroup of operators and their application to solving nonlocal problems, method of time iscretization and its applications to noncal problems, Galerkin approximation of solutions. Fourier Series method to nonlocal problems, Laplace transform method to nonlocal problems, certain problems in control theory modeled as nonlocal problems and their wellposedness.

MTH 661 **BIO-MECHANICS** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Introduction to bio-mechanics, Circulatory system, Pressure & flow in arterial system, Elastic & non-Newtonian effects on blood flow. Arterial diseases, Dialysis, Artificial kidneys. Human joints & their mechanism, Human joint lubrication; Mucus transport in lung.

MTH 662 **NAVIER-STOKES EQUATION** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Navier-Stokes equations, derivation, properties & historical perspective, Potential flows; Eulers, Stokes & Oseens equations; Free surface phenomena; Strong & weak solutions of basic equations; Existence, Uniqueness and properties of solutions.

MTH 664 **TRIBOLOGY** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

The fundamentals of lubrication, friction & wear. Boundary lubrication, Hydrodynamic lubrication, Elastohydrodynamic lubrication. Compressibility & thermal effects, Non- Newtonian lubrication, Roughness effects, Magneto-hydro-dynamic effects, Application to engineering & human systems.

MTH 665 **ENVIRONMENTAL DYNAMICS AND POLLUTION** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Our environment and its characteristics, Atmospheric motion, Basic equations, Atmospheric waves; Atmospheric turbulence, Logarithmic velocity profile, Diffusion equation; Environmental pollution and dispersion of pollutants. Effects of greenbelt and rain washout on dispersion.

MTH 666 **MATHEMATICAL THEORY OF ENVIRONEMNTAL BIOLOGY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Introduction to environmental biology, environmental pollution & population dynamics. Diffusion of pollutants and toxicants, Their effects on biological species, Models of population interaction with environmental effects and their analyses.

MTH 669 **THEORY OF STABILITY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Stabililty of fluid flows; Benard convection, Poisseuille flow, Rotatory Couette flow. Rayleigh-Taylor and Kelvin-Helmholtz problems. Nonlinear stability limits, Supercritical and subcritical regimes.

MTH 672 **COMBINATORIAL OPTIMIZATION** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Optimization problems; Convex sets & functions, Algorithms & complexity; Analysis of algorithms. Polynomial time algorithms; Strongly poly. algorithms for special LPs; NP- complete problems, Integer linear programming, Pseudo-poly. algorithm & strong NP-completeness. Approximation algorithms. Heuristics.

MTH 673 **CONVEX ANALYSIS AND OPTIMIZATION** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Convex functions, Separation theorems, Krein-Milman theorem, Reflexivity, Directional derivatives, Sub-gradients, Convex programs, Kuhn-Tucker theory, Lagrange multipliers, Conjugate functions, The Fenchel-duality theorem, Ekelands variational principle, Phelps extremization principle.

MTH 675 **ADVANCED GRAPH THEORY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Graphs, Groups, Schur functions, Polya's theorem, de Burijn's theorem, Redfield's theorem, Matroids, Transversal theory, Hypergraphs, Planarity, Colourability, Four colour problem.

MTH 680 **ELEMENTARY STOCHASTIC PROCESSES** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Markov chain, Chapman- Kolmogorov equation, Classification of states, Stationary distributions, Birth & death processes, Kolmogorov forward & backward equations. Poisson process; Strictly stationary and covariance stationary processes, Processes with independent increments; Continuity.

MTH 681 **STATISTICAL DECISION THEORY** **Prereq. #**

Decision function, Risk function, Optimal decision rules, Admissibility & completeness, The minimax theorem, The complete class theorem, Sufficient statistics. Invariant decision problems, Admissible & minimax invariant rules, The Pitman estimates, Estimation of a distribution function.

MTH 682 **ORDER STATISTICS** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Basic distribution theory, Moments of order statistics including recurrence relations, Bounds and approximations, Estimation of parameters, Life testing, Short cut procedures, Treatment of outliers, Asymptotic theory of extremes.

MTH 683 **NON-PARAMETRIC INFERENCE** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Order statistics, Tests of goodness of fit, Sign & signed rank tests, Wald-Wolfowitz, Kolmogorov-Smirnov, Median & Mann-Whitney tests, Linear rank tests for the location problem & scale problem, Measures of association, Asymptotic relative efficiency.

MTH 684 **STATISTICAL SIMULATION, DATA ANALYSIS AND MODEL BUILDING** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Introduction to simulation & Monte-Carlo studies; Generation of random variables. Interactive computational & graphical techniques in model building; Data based inference methods such as Jack-Knife, Bootstrap and cross-validation techniques; Use of statistical packages in data analysis.

MTH 685 **TIME SERIES ANALYSIS: FORECASTING AND CONTROL** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Linear stationary processes, Autocovariance & spectral density functions & moving average processes, Linear non-stationary processes, Model estimation & identification, Forecasting, Transfer function models, Design for discrete control.

MTH 686 **NON-LINEAR REGRESSION** **Prereq. #**
L-T-P-D-[C]
3-0-0-0-[4]

Estimation methods, Commonly encountered problems in estimation, Statistical inference, Multiresponse non-linear model, Asymptotic theory, Computational methods.

MTH 687 **RANKING, SELECTION & MULTIPLE DECISIONS** **Prereq. #**
L-T-P-D-[C]
3-1-0-0-[4]

The philosophy of ranking & selection, Indifference zone approach & subset selection (Elimination) approach, Procedures for complete ranking & selecting the best out of populations, Nonparametric formulations, Estimation of ordered parameters and other related topics.

MTH 688 — **TESTING OF HYPOTHESES II** — **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Neyman-Pearson lemma & its generalization. UMP & UMPU tests. SPRT & its properties. Distribution-free statistics, Linear rank test statistics, U-statistics, Asymptotic distributions of test statistics, ARE of tests. Bayes, Invariant and minimax, Randomization & permutation tests.

MTH 689 — **LINEAR AND NON-LINEAR MODELS** — **Prereq.#**

L-T-P-D-[C]
3-0-0-0-[4]

Generalized inverse, Eigen values & canonical reduction of matrices, Least square theory, Regression analysis. Unified theory of least squares, Variance component estimation, Minimum mean square error estimation & ridge regression, Generalised linear and non-linear models.

MTH 690 — **APPLIED NUMERICAL METHODS** — **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Fortran IV, Interpolation and approximation, Numerical integration, Numerical solution of a system of linear algebraic equations, Inverse of a matrix. Eigen-values and eigen-vectors of matrices. Numerical solution of ordinary & partial differential equations.

MTH 691 — **NUMERICAL LINEAR ALGEBRA** — **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Triangular form, Matrix norms, Conditioning of linear systems, Direct methods (Gauss, Cholesky, Householder), Iterative methods (Jacobi, Gauss-Seidel, Relaxation) for solving linear systems, Computing of eigenvalues & eigen-vectors (Jacobi, Givens-Householder, Q-R, Inverse methods), Conjugate gradient method & its preconditioning.

MTH 692 — **NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS** — **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Introduction. Runge-Kutta methods -derivation, error bounds and error estimates. Weak stability theory for Runge-Kutta methods. Order and convergence of the general explicit one-step methods. Linear multi-step methods -derivation, order consistency, zero-stability and convergence. Weak stability theory for general linear multi-step methods. Predictor-Corrector methods. Stiff systems.

MTH-693 — **NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS** — **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Basic linear algebra - vector and matrix norms and related theorems. Parabolic equations in one and two space dimensions - explicit and implicit formulae. Consistency, stability and convergence. Iterative methods for linear systems.

Split operator methods. Multilevel difference schemes. Nonlinear equations. Elliptic Equations - Dirichlet, Neumann and mixed problems. Direct factorization methods and successive over-relaxation (S.O.R.). ADI and conjugate gradient methods. Hyperbolic equations. First order hyperbolic systems in one and two space dimensions-stability and convergence. Second order equations in one and two space dimensions. The Galerkin method and applications.

MTH 694 **COMPUTATIONAL FLUID DYNAMICS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Conservation laws, Weak solutions & shocks, Monotone difference schemes, Total variation diminishing schemes, Godunov-type schemes, Essentially nonoscillatory methods, Flux limiters.

MTH 695 **INTRODUCTION TO MATHEMATICS OF CAGD (COMPUTER AIDED GEOMETRIC DESIGN)** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

B-splines, Be'zier curves, Splines in Bezier form, Geometric continuity, Tensor product, Bezier surfaces, Composite surfaces and spline interpolation, Geometric continuity for surfaces.

MTH 696 **SPECTRAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Galerkin, Collocation & Tau methods, Spectral approximation, The Fourier system, Continuous & discrete Fourier expansion, Orthogonal polynomials in (-1,1), Fundamentals of spectral methods for PDEs, Temporal discretization, The Galerkin- Collocation method, Implicit spectral equations, Case of nonsmooth solutions.

MTH 697 **FINITE ELEMENT METHOD: BASIC & APPLICATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Introduction: Weighted Residual and Variational Approaches; Element Shape Functions; Curved and Isoparametric Elements' FEM for Elliptic; Parabolic and Hyperbolic Equations; Error Estimates; FEM Computations - Some Preprocessing and Processing Methods; Flow Analysis - Psi-Omega and UVP Approaches; Upwind Strategies; Recent Trends in FEM; Parallel FEM.

MTH 698 **PARALLEL NUMERICAL ALGORITHMS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Fundamentals of parallel computing; Parallel techniques and algorithms; Parallel algorithms for linear algebriac equations; Design of parallel algorithms for eigen value problem; Parallel issues of factorization : singular- value decomposition and related problems; Parallel implementation of classical iterative methods; Conjugate gradient method; Parallel methods for ordinary and partial differential equations.

MTH 699 **PARTIAL DIFFERENTIAL EQUATIONS ON PARALLEL COMPUTERS Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Introduction to parallel computers; Parallel fdm-ADI algorithm, Multigrid method; Conjugate gradient method, Pre-conditioned conjugate gradient method; Parallel fem - domain decomposition method; Parallel time stepping algorithm, Applications from CFD + Project.

MTH 700 **NUMERICAL METHODS FOR SINGULAR PERTURBATON PROBLEMS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Examples of singular perturbation problems, Analytical behaviour of solutions, Asymptotic expansions (brief description), Turning point problem, Numerical methods based on FInite Differance, Finite Element and Finite Volume for singular perturbation problems in ODE;s and PDE;s, convergence analysis Adaptive methods.

MTH 701 **MODAL LOGIC** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Modal Propositional Logic-Systems K, T, D, S4, S5, B; Automated Proof Methods, Decidability; Consistency, Frames, Canonical Models, Completeness; Finite Models, Incompleteness.

Algebraic semantics-Lindenbaum-Tarski Algebras, Jonsson-Tarski Theorem, Goldblatt-Thomason Theorem.

Modal Predicate Logic-Completedness; Automated Proof Methods; Identity. some Modal Systems and applications-Temporal, dynamic and epistemic Logics, Topology via Modal Logic

MTH 730 **DIMETRAL DIMENSIONS & NUCLEARITY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Operators in Hilbert spaces, Trace of operators; Nuclearity; Nuclearity of operators and their characterisations; Diametral dimensions & their relationships with nuclearity; Bases in nuclear spaces.

MTH 731 **REPRESENTATIONS OF COMPACT & NILPOTENT LIE GROUPS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Unitary representations, Irreducibility, Characters, Peter- Weyl theorem, Fourier series of square integrable functions. The classical groups. Irreducible representations of SU(2). Lie algebras and their representations, Representations of SO(3), Spherical harmonics. Basic theory of nilpotent Lie groups. Elements of Kirillov theory.

MTH 732 **REPRESENTATION THEORY OF FINITE GROUPS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Basic representation theory, Irreducible representation, Equivalence and unitary equivalence, Construction of new representation, Character of a representation, Schur's lemma and its applications, Schur's orthogonality relations, Schur's theory of characters, induced representations, Frobenius reciprocity, group algebra C[G], Plancherel, Forier Inversion theorems, Some applications, Representations of S_n and A_n for small values of n.

MTH 733 **REPRESENTATION THEORY OF LINEAR LIE GROUPS**

Prereq. M.Sc. Level Analysis, #

L-T-P-D-[C]
3-0-0-0-[4]

Representation theory of Compact groups; Peter Weyl Theorem. Linear Lie Groups; The Exponential map, Lie Algebra, Invarient Differential Operaters. Representations of the group and its Lie Algebra. Fourier Analysis on SU(2) and SU(3). Representation theory of the heisenberg Group and some Harmonic Analysis. Representation of the Euclidean Motion Group.

MTH 734 **BANACH ALGEBRAS, C* ALGEBRAS AND SPECTRAL THEORY**

Prereq. #

L-T-P-D-[C]
3-0-0-0-[4]

Elementary properties of Banach Algebras and examples; Ideals and quotients, the Spectrum, the Riesz Functional Calculas.Abelian Banach Algebras, C* Algebras; Representations of C* Algebras and the Gelfand- Naimark -Segal Construction. Normal Operators on Hilbert Space, Spectral measure and representation of abelian C* algebras; The Spectral theorem; Some applications.

MTH 735 **TOPICS IN FOURIER ANALYSIS ON EUCLEDIAN SPACES** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

L1 and L2 Theory of Fourier transform, schwartz space and tempered distribution, pointwise pincare inequality, Housdroff-Young inequality, Khinchin's inequality, Uncertaininty principles, Bernstein's inequality for ellepsoid and disc, stationry phase and nonstationary phase, restriction problem, stein-tomas restriction theorem, Housdorff measures, sets with maximal fourier dimension, Kakeya problem, Fefferman - Bourgain theorem.

MTH 736 **FOURIER ANALYSIS AND DISTRIBUTION THEORY**

Prereq. #

L-T-P-D-[C]
3-0-0-0-[4]

Introduction, Test function spaces, Calculus with distributions, supports of distributions, Structure theorems, convolutions, Fourier transforms, L^1, L^2 theory of Fourier Transform, Tempered distributions, Paley-Wiener theorem, wiener-Tauberian theorem, Applications of distributions theory and Fourier transform to differential equations.

MTH 737 L-T-P-D-[C] 3-0-0-0-[4]

THE THEORY OF OPERATOR SPACE **Prereq. None**

Completely Bounded Maps, Minimal Tensor Product, Ruan's Theorem, Basic Operations, Minimal and Maximal Operator Space Structures, Projective Tensor Profuct, The Haagerup Tensor Product, Characterization of Operator Algebras, The Operator Hilbert Space.

MTH 738 L-T-P-D-[C] 3-0-0-0-[4]

THEORY OF INTERPOLATION

Distribution Functions and Decreasing Rearrangements, Rearrangement Invariant Spaces, The Spaces L1+L and L Interpolation Spaces, Hilbert Transform and Operations of joint Weak Type, The Riesz Thorin Convexity Theorem Complex Interpolation, Stein's Interpolation Theorem for Analytic Familites. The Marcinkiewicz Interpolation Theorem Restricted Weak Type, Orlicz Spaces, The K- Method Besov Spaces Sobolev Type Embedding Therem.

MTH 751 L-T-P-D-[C] 3-0-0-0-[4]

ALGEBRA **Prereq. None**

Groups, Basic properties, Isomorphism theorems, Permutation groups, Sylow Theorems, Structure theorem for finite abelian groups, Rings, Integral domains, Fields, division rings, Ideals, Maximal ideals, Euclidean rings, Polynomial ring over a ring, Maximal & Prime ideals over a commutative ring with unity, Prime avoidance theorem and Chinese Remainder theorem, Field Extension, Cramer's rule, Algebraic elements and extensions, Finite fields.

Determinants and their properties, Systems of linear equations, Eigenvalues and Eigenvectors, Caley-Hamilton theorem, Characteristic and minimal polynomial, diagonalization, Vector spaces, Linear transformations, Inner product spaces.

MTH-752 L-T-P-D-[C] 3-0-0-0-[4]

MATHEMATICAL METHODS **Prereq. : None**

Calculus of Variations; Sturm Liouville Problem and Green's Function; Perturbation Methods and Similarity Analysis; Stability Theory.

MTH 753 L-T-P-D-[C] 3-0-0-0-[4]

ANALYSIS **Prereq. None**

Metric spaces, Open and closed sets, Compactness and connectedness, Completeness, Continuous functions (several variables and on metric spaces), uniform continuity C(X), X, compact metric space, Uniform convergence, compactness criterion, Differentiation, Inverse and Implicit fuction theorems. Riemann Integration, Lebesgue Integration, L^p-spaces.

Complex Analysis: Analytic functions, Harmonic conjugates, Cauchy theorems and consequences, Power series, Zeros of analytic functions, Maximum modulus theorem, Singularities, Laurent series, Residues. Mobius transformations.

Hilbert spaces: Inner product, Orthogonality, Orthonormal bases, Riesz Lemma, The space L^2 as a Hilbert space.

MTH 754 **PROBABILITY THEORY** **Prereq. None**

L-T-P-D-[C]
3-0-0-0-[4]

Algebras and sigma algebras; Measurable spaces; Methods of introducing probability measures on measurable space; Random variables; Lebesgue integral; Expectation; Conditional probabilities and conditional expectations with respect to sigma-algebras; Radon Nikodym theorem; Inequalities of random variables; Fubini's theorem; Various kinds of convergence of sequence of random variables; Convergence of probability measures; Central limit theorem; delta method; Infinitely divisible and stable distributions; Zero-or-One laws; Convergence of series; Strong law of large numbers; Law of iteratedlogarithm; Matringales and their basic properties.

MTH-755 **STATISTICAL INFERENCE** **Prereq. None**

L-T-P-D-[C]
3-0-0-0-[4]

Population and samples; Parametric and nonparametricmodels; Exponential and location-scale families; Sufficiency and minimal sufficiancy; Complete statistics; Unbiased and UMVU estimation; Asymptotically unbiased estimators; Method of moments; Bayes estimators; Invariance; Minimaxity and admissibility; The method of maximum likelihood; Asymptotically efficient estimation; Variance estimation; The jacknife; The bootstrap; The NP lemma; MLR; UMP tests for one and two sided hypotheses; Unbiased and similarity; UMPU tests in exponential families; Invariance and UMPI tests; LR tests; Asymptotic tests based on likelihoods; Chi-square tests; Bayes tests; Pivotal quantities; Inverting acceptance regions of tests; The Bayesian confidence interval; Prediction sets; Length of confidence intervals; UMA and UMAU confidence sets; Invariant confidence sets.

MTH 761 **HYDRODYNAMIC STABILITY**

Prereq. MTH 461 #

L-T-P-D-[C]
3-0-0-0-[4]

Basic concepts of linear theory, stability, instability, neutral curves, Marginal stability; thermal instability and Rayleigh-Benard problem: governing equations, deriviation of stability equations and general characteristics, free-free, rigid-free and rigid-rigid boundary conditions, cell patterns, experimental observations; parallel shear flow instability: derivation of the Orr-sommerfeld equations, basic properties, Squires' transformations, inviscid theory, Rayleigh's criterion and Fjortoft's theorem, matching conditions for broken line profiles; Bioconvection problem: governing equations and derivations of stability conditions: gravitactic, gyrotactic and chemotactic micro-organisms; Weakly nonlinear theory: basic concepts, derivation of the amplitude equation through compatibility conditions, application of the Weakly nonlinear theory to Benard convection, bioconvection.

MTH 762 **CARDIO VASCULAR MODELLING**

L-T-P-D-[C]
3-0-0-0-[4]

The physical problem, principles of circulation heart, modelling of vessel walls, blood flow in Artries, blood flow in veins. Micro-circulation, coronary blood flow. ALE formulation of fluid motion in moving domains, analysis of incompressible NS equations, some numerical results.

MTH 781 **STATISTICAL PATTERN RECONGNITION** **Prereq.: ESO 209#**

L-T-P-D-[C]
3-0-0-0-[4]

Introduction to pattern recongnition supervised and unsupervised classification. Dimension redution techniiques: principal component analysis, multidimensional scaling features for maximum linear separation projection pursuit Parametric methods for discriminant analysis: Fisher's linear discriminant function. linear and quadratic discriminant analysis regularized discriminant analysis. Linear and nonlinear support vector machines. Cluster analysis: hierarchical and non-hierarchical techniques classification using Gaussian mixtures. Data depth: different notions of depth, concept of multivariate median, application of depth in supervised and unsupervised classification.

MTH 782 **TOPICS IN PROBABILITY AND STOCHASTIC PROCESSES**
Prereq. MTH 385 or #

L-T-P-D-[C]
3-0-0-0-[4]

Conditional probabilities and conditional expectations with respect to a s-algebra, Construction of a process with a given finite dimensional distribution, The Hilbert space L^2, Gaussian systems, Markov processes with continuous state space, Renewal theory, Stationary processes and Ergodic theory, Martingales, Branching processes.

MTH 783 **ADVANCED STOCHASTIC PROCESSES** **Prereq. MTH 488/MTH 782 or #**

L-T-P-D-[C]
3-0-0-0-[4]

Weak convergence of stochastic processes, Stochastic calculus, Theory of continuous time Markov processes.

MTH 784 **STATISTICAL RELIABILITY THEORY** **Prereq. ESO 209, #**

L-T-P-D-[C]
3-0-0-0-[4]

Reliability concepts and measures, Components and systems, Coherent systems, Cuts and Paths, Modular decomposition, Bounds on system reliability; Life distributions, Survival functions, Hazard rate, Residual life time, Mean residual life function, Common life distributions, Proportional Hazard models; Notions of aging, Aging properties of common life distributions, closure under formation of coherent structures, Convolutions and mixture of these cases; Univariate and bivariate shock models, Notions of bivariate and multivariate and depedence; Maintainance and replacement policies, Availabilityof repairable systems, Optimization of system reliability with redundancy.

MTH 785 **ECNOMETRIC THEORY** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Multiple linear model , estimation of parameters under spherical and non-spherical disturbances by least squares and maximum likelihood methods, tests of hypothesis, R^2 and adjusted R^2. Prediction, within and outside sample predictions. Problem of structural change, tests for structural change. Use of dummy variable. Specification error analysis related to explanatory variables, inlusion and deletion of explanatory variables. Idea of Stein-rule estimation.Exact and stochastic linear restrictions, restricted and mixed regression analysis. Multicollinearity, problem, implications and tools for handling the problem, ridge regression. Heteroskedasticity, problem and test, estimation under Hetero-skedasticity. Autocorrelation, Durbin-Watson test. Errors-in-variables, inconsistency of least squares method, methods of consistent estimation, instrumental variable estimation. Seemingly unrelated regression equation model, least squares, generalized least squares and feasible generalized least squares estimators. Simultaneous equations model, structural and reduced forms, rank and order conditions for identifiability, indirect least squares, two stage least squares and limited information maximum likelihood methods of estimation. Additional topics like as Panel data models and unit roots & co-integration.

MTH 786 **MULTIOBJECTIVE OPTIMIZATION, THOEY, METHODS, AND APPLICATIONS** **Prereq. #**

L-T-P-D-[C]
3-0-0-0-[4]

Theory: Fundamentals of Optimisation with single objective. Karush-Kuhn-Tucker Conditions. Langrangian Multipliers. Introduction to multiobjective optimization problem. Solution Concepts (Efficency, Weak Efficiency and Proper Efficiency). Scalarization Techniques. Structure of the efficient set. Karush-Kuhn-Tucker Conditions for multiobjective problem. Lexicographic ordering.

Methods : Classical methods- weighted-sum approaches, e-constraint method. Tchebycheff methods. Utility function methods. interactive methods.

Evolutionary methods - Fundamental principles, differences with classical methods, non-elitist methods (NSGA, MOGA, NPGA etc.). elitist method (NSGA-II, SPEA, PESA etc.), constrained methods, salient advaned techniques (scale-up to large number of objectives, parallel computing, convergence issues, hybrid classical-evolutionary methods etc.,).

Applications: Case studies from science and engineering domains, relevance to innovative design.

MTH 791 **FINITE ELEMENT COMPUTATIONS** **Prereq. MTH 697 or #**
L-T-P-D-[C]
3-0-0-0-[4]

Basic of finite element approximation; Mesh generation; Global problem issues systems of linear equations; Sparse systems; Eigen value problems; Issues in time dependent problem calculations; Parallel computing aspects; Other current trends in fem computations + Project.

MTH 799 **RESEARCH**

STA 799 **RESEARCH**