Indian Institute of Technology Kanpur

COURSES OF STUDY

2024

Indian Institute of Technology Kanpur
KANPUR-208016

MATHEMATICS AND STATISTICS

Template for 3rd to 8th semester for BS program in Mathematics and Scientific Computing					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 EME (9-11)	SCHEME-3 HSS-I (9-11)	SCHEME-4 HSS-II (9)	MTH305 (11)	SCHEME-5 HSS-II (9)	SCHEME-6 HSS-II (9)
MTH201 (11)	ESC201 (14)	MTH421 (11)	MTH424 (11)	DE-4 (9)	DE-6 (9)
MTH302 (11)	MTH204 (11)	MTH403 (11)	MTH430 (10)	DE-5 (9)	OE-4 (9)
E/SO-1: MSO205 (11)	MTH301 (11)	E/SO-3: ESO207 (12)	DE-2 (9)	OE-1 (9)	OE-5 (9)
E/SO-2 (9-11)	MTH308 (10)	DE-1 (9)	DE-3 (9)	OE-2 (9)	OE-6 (9)
				OE-3 (9)	
51-55	55-57	52	50	54	45

Credit table for BS program in Mathematics and Scientific Computing		
Course type	Allowable Credit range	Credits in the department template
Institute Core (IC)	112	112
E/SO	18-45	32-34
Department requirements	144-179	162 (108 DC + 54 DE)
Open electives (OE)	51-57	54
SCHEME	54-58	54-58
Total for 4-year BT/BS	391-420	414-420

Template for 3rd to 8th semester for BSH program in Mathematics and Scientific Computing					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 EME (9-11)	SCHEME-3 HSS-I (9-11)	SCHEME-4 HSS-II (9)	MTH305 (11)	SCHEME-5 HSS-II (9)	SCHEME-6 HSS-II (9)
MTH201 (11)	ESC201 (14)	MTH421 (11)	MTH424 (11)	DE-4 (9)	UGP-2 (9)
MTH302 (11)	MTH204 (11)	MTH403 (11)	MTH430 (10)	OE-1 (9)	OE-4 (9)
E/SO-1: MSO205 (11)	MTH301 (11)	E/SO-3: ESO207 (12)	DE-2 (9)	OE-2 (9)	OE-5 (9)
E/SO-2 (9-11)	MTH308 (10)	DE-1 (9)	DE-3 (9)	OE-3 (9)	OE-6 (9)
				UGP-1 (9)	
			DEH-1 (9)	DEH-2 (9)	DEH-3 (9)
51-55	55-57	52	59	63	54

- **CPI criterion for BSH: 8.5**

Template for 3rd to 8th semester for BSM program in Mathematics and Scientific Computing					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 EME (9-11)	SCHEME-3 HSS-I (9-11)	SCHEME-4 HSS-II (9)	MTH305 (11)	SCHEME-5 HSS-II (9)	SCHEME-6 HSS-II (9)
MTH201 (11)	ESC201 (14)	MTH421 (11)	MTH424 (11)	OE-1 (9)	OE-3 (9)
MTH302 (11)	MTH204 (11)	MTH403 (11)	MTH430 (10)	OE-2 (9)	MTB-4 (9)
E/SO-1: MSO205 (11)	MTH301 (11)	E/SO-3: ESO207 (12)	DE-2 (9)	MTB-1 (9)	MTB-5 (9)
E/SO-2 (9-11)	MTH308 (10)	DE-1 (9)	DE-3 (9)	MTB-2 (9)	MTB-6 (9)
				MTB-3 (9)	
51-55	55-57	52	50	54	45

Dual degree program in Mathematics and Scientific Computing

BS-MS PG Part – Category A (from the same program)			
COURSES			
Semester 9		Semester 10	
MS Project (PGP-1, PGP-2)	18	MS Project (PGP-3, PGP-4)	18
DE PG - 1	09	DE PG - 3	09
DE PG - 2	09	DE PG - 4	09
OE PG – 1/DE PG-5	09	OE PG – 2/DE PG-6	09
Total	45		45

Minimum credits in MS part for graduation: 90

BS-MS PG Part – Category B (from other programs)					
UG pre-requisites		PG Requirements			
Odd Semester	Even Semester	IX Semester		X Semester	
MTH201 (11)	MTH204 (11)	MS Project (PGP-1, PGP-2)	18	MS Project (PGP-3, PGP-4)	18
MTH302 (11)	MTH301 (11)	DE PG - 1	09	DE PG - 3	09
MTH305 (11)	MTH308 (10)	DE PG - 2	09	DE PG - 4	09
MTH403 (11)	MTH421 (11)	OE PG – 1/DE PG-5	09	OE PG – 2/DE PG-6	09
MTH424 (11)	MTH430 (10)				
55	53		45		45

Double Major: Second Major in Mathematics and Scientific Computing

Double Major	
Odd Semester	Even Semester
Pre-Requisites	
ESO 207 (12)	MSO201 (11) or MSO 205 (11) – Introduction to Probability Theory (Odd Semester)
Mandatory MTH Courses	
MTH201 (11)	MTH204 (11)
MTH302 (11)	MTH301 (11)
MTH305 (11)	MTH308 (10)
MTH403 (11)	MTH421 (11)
MTH424 (11)	MTH430 (10)
55	53

Template for 3rd to 8th semester BS program in Statistics and Data Sciences					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 HSS-I (9-11)	SCHEME-3 EME (9-11)	MTH442 (10)	SCHEME-4 HSS-II (9)	SCHEME-5 HSS-II (9)	SCHEME-6 HSS-II (9)
ESC201 (14)	MTH211 (11)	MTH441 (10)	MTH422 (10)	DE-1 (9)	DE-4 (9)
MTH301 (11)	MTH210 (10)	E/SO-3: ESO207 (12)	MTH314 (10)	DE-2 (9)	DE-5 (9)
ESO/SO-1: MSO205 (11)	MTH212M (06) Modular 1st half)	E/SO-4 MSO202M (6)	MTH312 (5)	DE-3 (9)	OE-5 (9)
MTH207M (6) (Modular 2nd half)	MTH209 (5)		MTH443 (10)	OE-3 (9)	OE-6 (9)
MTH208 (05)	ESO/SO-2 (9)	OE-1 (09)	OE-2 (09)	OE-4 (9)	
56-58	50-52	47	53	54	45

Credit table for BS program in Statistics and Data Sciences		
Course type	Allowable Credit range	Credits in the department template
Institute Core (IC)	112	112
E/SO	18-45	38
Department requirements	144-179	154 (109 DC + 45 DE)
Open electives (OE)	51-57	54
SCHEME	54-58	54-58
Total for 4-year BT/BS	391-420	412-416

Template for 3rd to 8th semester BSH program in Statistics and Data Sciences					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 HSS-I (9-11)	SCHEME-3 EME (9-11)	MTH442 (10)	SCHEME-4 HSS-II (9)	SCHEME-5 HSS-II (9)	SCHEME-6 HSS-II (9)
ESC201 (14)	MTH211 (11)	MTH441 (10)	MTH422 (10)	DE-1 (9)	DE-2 (9)
MTH301 (11)	MTH210 (10)	E/SO-3: ESO207 (12)	MTH314 (10)	OE-3 (9)	DE-3 (9)
ESO/SO-1: MSO205 (11)	MTH212M (06) Modular 1st half)	E/SO-4 MSO202M (6)	MTH312 (5)	OE-4 (9)	OE-6 (9)
MTH207M (6) (Modular 2nd half)	MTH209 (5)		MTH443 (10)	OE-5 (9)	UGP-2 (9)
MTH208 (05)	ESO/SO-2 (9)	OE-1 (09)	OE-2 (09)	UGP-1 (9)	
			DEH-1 (9)	DEH-2 (9)	DEH-3 (9)
56-58	50-52	47	62	63	54

- **CPI Criterion for BSH: 8.5**

Template for 3rd to 8th semester BSM program in Statistics and Data Sciences					
Semester 3	Semester 4	Semester 5	Semester 6	Semester 7	Semester 8
SCHEME-2 HSS-I (9-11)	SCHEME-3 EME (9-11)	MTH442 (10)	SCHEME-4 HSS-II (9)	SCHEME-5 HSS-II (9)	SCHEME-6 HSS-II (9)
ESC201 (14)	MTH211 (11)	MTH441 (10)	MTH422 (10)	DE-1 (9)	DE-2 (9)
MTH301 (11)	MTH210 (10)	E/SO-3: ESO207 (12)	MTH314 (10)	OE-2 (9)	OE-3 (9)
ESO/SO-1: MSO205 (11)	MTH212M (06) Modular 1st half)	E/SO-4 MSO202M (6)	MTH312 (5)	MTB-2 (9)	MTB-5 (9)
MTH207M (6) (Modular 2nd half)	MTH209 (5)		MTH443 (10)	MTB-3 (9)	MTB-6 (9)
MTH208 (05)	ESO/SO-2 (9)	OE-1 (09)	MTB-1 (9)	MTB-4 (9)	
56-58	50-52	47	53	54	45

Dual degree program in Statistics and Data Science

BS-MS PG Part – Category A (from the same program)					
COURSES					
IX Semester			X Semester		
MS Project – (PGP 1, PGP 2)		18	MS Project - (PGP 3, PGP 4)		18
DE PG - I		09	DE PG-II		09
OE PG - I		09	OE PG-III		09
OE PG - II		09	OE PG - IV		09
Total		45			45

Minimum credit requirement in MS part for graduation: 90

BS-MS PG Part – Category B (from other programs)					
UG Pre-Requisites					
Odd Semester			Even Semester		
MTH301 – Analysis I		11	MTH211 – Theory of Statistics		11
			MTH210 – Statistical Computing		10
MTH207M – (Modular) Matrix Algebra and Linear Estimation (module II)		06	MTH212M – (Modular) Elementary Stochastic Processes-I		06
MTH442- Time Series Analysis		10	MTH422-An Introduction to Bayesian Analysis		10
MTH441 – Linear Regression and ANOVA		10	MTH314 – Multivariate Analysis		10
MTH208 - Data Science Lab I		05	MTH443-Statistical & AI Techniques in Data Mining		10
			MTH209 – Data Science Lab II		05
			MTH312 – Data Science Lab III		05
Total		42			67
PG Requirement					
Odd Semester			Even Semester		
MS Project – (PGP 1, PGP 2)		18	MS Project - (PGP 3, PGP 4)		18
DE PG - I		09	DE PG-II		09
OE PG - I		09	OE PG-III		09
OE PG - II		09	OE PG - IV		09
Total		45			45

Double Major: Second Major in Statistics and Data Science					
Odd Semester			**Even Semester**		
Pre-Requisites					
MSO 205 **or** MSO 201 **or** HSO 201 **or** CS 203		11			
MSO 202M **or** MTH403		06			
ESO 207		12			
Mandatory MTH Courses					
MTH 207M		06	MTH 209		05
MTH 208		05	MTH 211		11
MTH 301		11	MTH 210		10
MTH 441		10	MTH 212M		06
MTH 442		10	MTH 312		05
			MTH 314		10
			MTH 422		10
			MTH 443		10
Total		**42**			**67**

Template for the 2 year MSc programme in Mathematics

YEAR I				YEAR II			
Semester I		Semester II		Semester III		Semester IV	
Course	L-T-P-A [C]	Course	L-T-P-A [C]	Course	L-T-P-A [C]	Course	L-T-P-A[C]
MTH201A	3-1-0-0 [11]	MTH204A	3-1-0-0 [11]	MTH403A	3-1-0-0 [11]	OE-2	3-0-0-0 [09]
MTH202A	3-1-0-0 [11]	MTH424A	3-1-0-0 [11]	DE-1	3-0-0-0 [09]	OE-3	3-0-0-0 [09]
MTH301A	3-1-0-0 [11]	MTH308B	3-0-1-0 [10]	OE-1	3-0-0-0 [09]	OE-4	3-0-0-0 [09]
MTH409A	2-1-1-0 [09]	MTH305A	3-1-0-0 [11]	DE-2	3-0-0-0 [09]	DE-4	3-0-0-0 [09]
MTH421A	3-1-0-0 [11]	MTH304A	3-1-0-0 [11]	DE-3/ MTH598A	3-0-0-0 [09]	DE-5/ MTH599A	3-0-0-0 [09]
ELC112	2-1-0-1 [09]						
	62		54		47		45

DC : 118 DE : 45 OE : 36 ELC : 09 TOTAL : 208

M.Sc Statistics (2 year) Curriculum

Semester I	Semester II	Semester III	Semester IV
MSO205A - Introduction to Probability Theory (3-1-0-0) **[11]**	MTH309A - Probability Theory (3-1-0-0) **[11]**	MTH441A - Linear Regression and ANOVA (3-0-1-0) **[10]**	MTH314A - Multivariate Analysis (3-0-1-0) **[10]**
(Modular – Part 1) MTH432A - Sampling Theory (3-1-0-0) **[06]**	(Modular – Part 1) MTH212A - Elementary Stochastic Processes I (3-1-0-0) **[06]**	MTH515A - Inference II (3-1-0-0) **[11]**	MTH312A - Data Science Lab 3 (1-0-2-0) **[05]**
(Modular – Part 2) MTH434A - Complex Analysis (3-1-0-0) **[06]**	(Modular – Part 2) MTH313A - Elementary Stochastic Processes II (3-1-0-0) **[06]**	MTH516A - Non-Parametric Inference (3-1-0-0) **[11]**	DE-2 **[09]**
MTH433A - Real Analysis (3-1-0-0) **[11]**	MTH418A - Inference I (3-1-0-0) **[11]**	DE-1 **[09]** / MTH 598A **[09]**	DE-3 **[09]**
MTH208A - Data Science Lab 1 (0-0-3-2) **[05]**	MTH210A - Statistical computing (3-0-1-0) **[10]**	OE-1 **[09]**	DE-4 **[09] /** MTH 599A **[09]**
MTH206A - Matrix Algebra and Linear Estimation (Module I) (3-1-0-0) **[06]**	MTH209A - Data Science Lab 2 (1-0-2-0) **[05]**		OE-2 **[09]**
MTH207A - Matrix Algebra and Linear Estimation (Module II) (3-1-0-0) **[06]**			
ELC112 (2-1-0-1) **[09]**			
60	49	50	51

Credits:
DC: 147
DE: 36
OE: 18
ELC: 09
Total: 210

DEPARTMENT OF MTH			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
IDC608	Computability Theory	3-0-0-0-9	Review of models of computation and Church-Turing thesis, Universal partial computable function and Kleene's S-n-m theorem, C.e. sets, Examples of algorithmic undecidability: MRDP theorem, Boone-Novikov theorem, Wang tiling problem, Strong reductions and Myhill's theorem, Simple and immune sets, Hyperimmune sets, Oracle computation, Turing degrees and the jump operator, Arithmetical hierarchy, Low and high sets, Martin's high domination theorem, Forcing constructions: Kleene-Post, Spector's exact pair, Recursively pointed trees and minimal degrees, Priority constructions: Friedberg-Mucnik theorem, Sacks splitting theorem, Computable ordinals and the hyperarithmetical hierarchy, Solovay's theorem, Measure and category on the Cantor space, Algorithmic genericity and randomness, Schnorr/Martin-Lof randomness and van-Lambalgnen theorem, Kolmogorov complexity and randomness, Current research topics. **Course References:** 1. Robert Soare, Turing Computability: Theory and Applications, Springer 2016. 2. Andre Nies, Computability and Randomness, Oxford University Press 2009. 3. Robert Downey and Denis Hirschfeldt, Algorithmic randomness and Complexity, Springer 2010.
MSO201	PROBABILITY AND STATISTICS	3-1-0-0-11	Probability: Axiomatic definition, properties, conditional probability, Bayes rule and independence of events. Random variables, distribution function, probability mass and densityfunctions, expectation, moments, moment generating function, Chebyshev's inequality. Special distributions; Bernoulli, binomial, geometric, negative binomial, hypergeometric, Poisson, exponential, gamma, Weibull, beta, Cauchy, double exponential, normal. Reliability and hazardrate, reliability of series and parallel systems. Joint distributions, marginal and conditional distributions, moments, independence of random variables, covariance and correlation. Functionsof random variables. Weak Law of large numbers and Central limit theorems. Statistics: Descriptive statistics, graphical representation of the data, measures of location and variability. Population, sample, parameters. Point estimation; method of moments, maximum likelihood estimator, unbiasedness, consistency. Confidence intervals for mean, difference ofmeans, proportions. Testing of hypothesis; Null and alternate hypothesis, Neyman Pearson fundamental lemma, Tests for one sample and two sample problems for normal populations, testsfor proportions. **Course Reference**: 1. Introduction to Mathematical Statistics, by R V Hogg, A Craig and J W McKean; 2. An Introduction to Probability and Statistics by V.K. Rohatgi &

			A.K. Md. E. Saleh; 3. Introduction to Probability and Statistics by S. Milton & J.C. Arnold; 4. Introduction to Probability Theory and Statistical Inference by H.J. Larson; 5. Introduction to Probability and Statistics for Engineers and Scientists by S.M. Ross
MSO202M	COMPLEX VARIABLES	3-1-0-0-6	Complex Numbers, Polar form, De-Moivre's formula, convergent sequence, continuity, Complex differentiation, Cauchy-Riemann equation, Applications, Analytic functions and Power series, Derivative of a power series, Exponential function, Logarithmic function and trigonometric functions, Contour and Contour integral, Anti-derivative, ML inequality, Cauchy's theorem, Cauchy Integral formula, examples, Evolution of contour integrals, Derivatives of analytic functions, Cauchy's estimate, Liouville theorem, Fundamental theorem of Algebra, Morera's theorem (without proof), Taylor's theorem, Examples, Computation of Taylor's series. Zeros of Analytic functions. Identity theorem, Uniqueness theorem, Applications, Maximum modulus principle, Laurent series, Computation of Laurent expansion, Cauchy residue theorem, Poles, Residue at a pole, Examples, Evaluation of real improper integrals of different forms, Linear fractional transformations. **Course Reference**: 1. E. Kreyszig, Advanced Engineering Mathematics. 2. R. V. Churchill and J. W. Brown, Complex Variables and Applications.
MSO203M	PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-6	Sturm Liouville BVP: introduction, examples. Sturm Liouville BVP: orthogonal functions, Sturm Liouville expansions. Fourier series, convergence of Fourier series, Fourier series with arbitrary period. Fourier series: sine and cosine series, half range expansion. Fourier integrals, Fourier: Legendre series. Fourier Transform. Introduction to PDE, linear, nonlinear (semi linear, quasi linear) examples, order of PDEs. First order (linear, semi linear) PDEs, interpretation, method of characteristics. First order (linear, semi linear) PDEs, general solutions. First order quasi linear PDEs, interpretation, method of characteristics, general solutions. Classification of 2nd order PDEs, Canonical form: hyperbolic equations. Canonical form: parabolic equations, elliptic equations. Wave equations: DAlembertfs formula, Duhamelfs principle. Wave equations: solutions for initial boundary value problems. Heat equation: uniqueness and maximum principle, applications. Heat equation: solutions for initial boundary value problems. Laplace and Poisson equations: Uniqueness and maximum principle for Dirichlet problem. Laplace and Poisson equations: BVP in 2D (rectangular, polar). Laplace and Poisson equations: BVP in 3D (spherical, cylindrical) **Course Reference**: 1. E. Kreyszig. Advanced Engineering Mathematics. (8th Edition); 2. T. Amarnath. An Elementary Course in Partial Differential Equations.
MSO205	INTRODUCTION TO	3-1-0-0-11	Basic definitions and ideas such as random experiment, sample space and event, Classical definition and relative

	PROBABILITY THEORY		frequency definition of probability, Axiomatic definition of probability, Elementary properties of probability function, Probability inequalities such as Boole's inequality and Bonferroni inequality. Conditional probability and its basic properties, Examples of conditional probability and multiplication law, Theorem of total probability and related examples, Bayes theorem and related examples, Independent events. Random variables and their distribution function, Induced probability space, Discrete and continuous random variables, Function of random variables (Discrete and Continuous), Expectation and moments of random variables, MGF of random variables and its application, Markov, Chebyshev and Jensen's inequality, Characteristics function and its application. Standard discrete distributions and their properties (e.g., Bernoulli, Binomial, Geometric, Negative Binomial, Hypergeometric, Poisson). Standard continuous distributions and their properties (e.g., Normal, Exponential, Gamma, Beta, Cauchy). Random vectors and their joint distribution functions, Marginal distribution, independent random variables, Conditional distribution of random vectors/variables, Expectation and moments of random vectors, Conditional Expectation, variance and covariance and their applications. Idea of limiting distribution, Convergence in distribution and probability, and related results, Convergence of moments and almost sure convergence, Various examples and counter examples. Weak law of large numbers, Central limit theorem, Applications, e.g., continuous mapping theorem and delta method.
MTH111M	SINGLE VARIABLE CALCULUS	3-1-0-0-6	Real number system: Completeness axiom, density of rationals (irrationals) in $\mathbb{R}$, convergence of a sequence, Sandwich theorem, Monotone sequences, Cauchy Criterion, Subsequence, Every bounded sequence has a convergent subsequence, convergence of a sequence satisfying Cauchy criterion, Limits and Continuity of functions, Boundedness of a continuous function on $[a, b]$, Existence of max of a continuous function on $[a,b]$, Intermediate value property, Differentiability, Necessary condition for local maxima, Rolles theorem and Mean Value theorem, Cauchy mean value theorem, L`Hospital rule, Fixed point iteration method (Picard's method), Newton's method, Increasing and decreasing function, Convexity, Second derivative test for max and min, Point of Inflection, Curve Sketching, Taylor's theorem and remainder, Convergence of series, Geometric and Harmonic Series, Absolute convergence, Comparison test, Cauchy Condensation test. Ratio test, Root test, Examples, Leibniz' theorem, Power series, Radius of convergence, Taylor Series, Maclaurin Series, Introduction to Riemann Integration, Integrability, The Integral existence theorem for continuous functions and monotone functions, Elementary properties of integral, Fundamental theorems of Calculus, Trapezoidal approximation, Simpson's Rule, Improper

			integral of first and second kind, Comparison test, Absolute convergence.
MTH112M	APPLICATION OF SINGLE VARIABLE CALCULUS & SEVERAL VARIABLE CALCULUS	3-1-0-0-6	Application of definite integral, Area between two curves, Polar coordinates, Graphs of polar coordinates, Area between two curves when their equations are given in polar coordinates, Volumes by slicing, Volumes by Shells and Washers, Length of a curve, Area of surface of revolution, Pappus's theorem, Review of vector algebra, Equations of lines and planes, Continuity and Differentiability of vector functions, Arc length for space curves, Unit tangent vector, Unit normal and curvature to plane and space curves, Binormal, Functions of several variables, Continuity, Partial derivatives, Differentiability, Differentiability implies continuity, Increment theorem, Chain rule, Gradient, Directional derivatives, Tangent plane and Normal line, Mixed derivative theorem, Mean value theorem, Minima and Saddle point, Necessary and sufficient conditions for Maxima, minima and Saddle point, The method of Lagrange multipliers, Double Integral, Fubini's theorem, Volumes and Areas, Change of variable in double integral. Special cases: Polar coordinates, Triple integral, Applications, Change of variable in triple integral. Special cases: Cylindrical and Spherical coordinates, Surface area, Surface integral, Line integrals, Green's theorem, Vector fields Divergence and Curl of a vector field, Stoke's theorem, The divergence theorem.
MTH113M	INTRODUCTION TO LINEAR ALGEBRA	3-1-0-0-6	*System of linear equations and matrices*: Matrices, System of linear equations; Elementary matrices, Invertible matrices, Gauss-Jordon method for finding inverse of a matrix; Determinants, Basic properties of determinants, Cofactor expansion, Determinant method for finding inverse of a matrix, Cramer’s Rule. *Vector space*: Vector space, Subspace, Examples; Linear span, Linear independence and dependence, Examples; Basis, Dimension, Extension of a basis of a subspace, Intersection and sum of two subspaces, Examples. *Linear transformation*: Linear transformation, Kernel and range of a linear map, Ranknullity theorem; Rank of a matrix, Row and column spaces, Solvability of system of linear equations. *Inner product space*: Inner product, Cauchy-Schwartz inequality, Orthogonal basis, Gram-Schmidt orthogonalization process; Orthogonal projection, Orthogonal complement, Projection theorem; Fundamental subspaces and their relations, Application (Least square solutions and least square fittings). *Eigenvalue and eigenvector*: Eigenvalues, Eigenvectors; Characterization of a diagonalizable matrix, Example, Diagonalization of a real symmetric matrix; Representation of a real linear maps by matrices (optional).
MTH114M	INTRODUCTION TO ORDINARY DIFFERENTIAL EQUATIONS	3-1-0-0-6	*First order ODEs*: Introduction to differential equations, Concept of solution, Geometrical interpretations; Separable form, Reduction to separable form; Exact equations, Integrating factors ; Linear equations, Bernoulli equations,

			orthogonal trajectories; Picard's existence and uniqueness theorem (without proof), Picard's iteration method; Numerical methods: Euler's method. *Second order linear ODEs*: Improved Euler's method. Fundamental system and general solutions of homogeneous equations, Wronskian, Reduction of order; Characteristic equations: real distinct roots, complex roots, repeated roots; Nonhomogeneous equations: methods of undetermined coefficients and variation of parameters; Extension to higher order differential equations, Euler-Cauchy equation, Qualitative properties of solutions, Sturm comparison theorem. *Series solutions of ODEs*: Ordinary points, Power series solutions; Regular singular points, Frobenius method; Legendre polynomials; Bessel functions. *Boundary value problems*: Sturm-Liouville boundary value problems, Orthogonal functions. *Laplace transform*: Laplace and inverse Laplace transforms, First shifting theorem, Transforms of derivative and integral, Differentiation and integration of transforms; Unit step function, Second shifting theorem, Convolution, Solution of initial value problems.
MTH201	A FIRST COURSE IN LINEAR ALGEBRA	3-1-0-0-11	Matrices: Elementary matrices, invertible matrices, Gauss-Jordon method, determinant, Systems of linear equations and Cramer's Rule. Vector spaces: Fields, Vector spaces over a field, subspaces, Linear independence and dependence, existence of basis, coordinates, dimension. Linear Transformations: Rank Nullity Theorem, isomorphism, matrix representation of linear transformation, change of basis, similar matrices, linear functional and dual space. Inner product spaces: Cauchy-Schwarz's inequality, Gram-Schmidt orthonormalization, orthonormal basis, orthogonal projection, projection theorem, four fundamental subspaces and their relations (relation between null space and row space; relation between null space of the transpose and the column space). Diagonalization: Eigenvalues and eigenvectors, diagonalizability, Invariant subspaces , adjoint of an operator, normal, unitary and self adjoint operators, Schur's Lemma, diagonalization of normal matrices, spectral decompositions and spectral theorem, applications of spectral theorem, Cayley-Hamilton theorem, primary decomposition theorem, Jordon canonical form, minimal polynomials, Introduction to bilinear and Quadratic forms: Bilinear and quadratic forms, Sylvester's law of inertia. Some applications: Lagrange interpolation, LU,QR and SVD decompositions, least square solutions, least square fittings, pseudo inverses. Reference materials: 1. Kenneth Hoffman and Ray Kunze: Linear Algebra, PHI publication. 2. Gilbert Strang: Linear Algebra and Its Applications, 4th edition. 3. Sheldon Axler: Linear Algebra Done Right, UTM, Springer.

MTH202	SET THEORY AND DISCRETE MATHEMATICS	3-1-0-0-11	Basic set theory: Unions, Intersections, Pairs, Powers, Relations and Functions, Partial Orders, Numbers, Peano's Axioms, Mathematical Induction, Finite and Infinite Sets, Families of sets: Product of sets(finite and infinite), More on relations and functions, Schroder-Bernstein Theorem, Countable and Uncountable Sets, Axiom of Choice, Zorn's Lemma, Cardinals and ordinals, Integers, Divisibility in Integers, GCD, Bezout's identity, modular arithmetic, Chinese remainder theorem, Fermat's little theorem, Euler Phi-function, Permutation, Combinations, Circular permutations, Binomial and Multinomial theorems, Solutions in nonnegative integers, Balls into Boxes-Pigeon-hole Principle, Inclusion-Exclusion Principle, Recurrence Relations, Generating Functions, generating functions from recurrence relation. Course references: 1. Kenneth Rosen: Discrete Mathematics and Its Applications, McGraw Hill Education; 7 th edition. 2. Donald Knuth, Oren Patashnik, and Ronald Graham: Concrete Mathematics, Addison-Wesley Professional. 3. David M. Burton: Elementary Number Theory.
MTH204	ABSTRACT ALGEBRA	3-1-0-0-11	Some set theoretic notions: Relations, Functions, Partitions, Division algorithm. Various binary operations and examples. Groups and their properties, Subgroups, Cyclic groups and its subgroups, Group of integers and its properties, Fundamental theorem of arithmetic. Properties of subgroups, Lagrange theorem. Normal subgroupand Quotient group, Homomorphism, Isomorphism theorems. Symmetric group, Cyclic decomposition of a permutation, Alternating group. Group action, Class equation, Cauchy’s theorem, Sylow theorems and their applications. Ring and its properties, Characteristic of a ring, Integral domain, Field, Division ring. Ideals and Quotient ring, Homomorphism, Isomorphism theorems. Polynomial ring, Unique factorization domain, Principal Ideal domain, Euclidean domain, Gaussian ring. **Course Reference**: 1. Contemporary Abstract Algebra, Joseph A Gallian (Narosa Publishing House, NewDelhi, 1998); 2. Algebra, Michael Artin (Prentice Hall of India, New Delhi, 1994); 3. Abstract Algebra, John B Fraleigh (Narosa Publishing House, New Delhi, 1988); 4. Abstract Algebra, David S Dummit and Richard M Foote (John Wiley & Sons, NewDelhi, 1999).
MTH205	INTRODUCTION TO FOURIER SERIES	3-1-0-0-11	Fourier series, Convolutions, Good kernels, Cesaro and Abel Summable, Convergence of Fourier series: Mean square, Pointwise convergence, Applications: Weyl equi-distribution, Isoperimetric inequality, Construction of continuous but nowhere differentiable function, Finite Fourier Analysis: on abelian groups, Characters as a total family, Fourier inversion and Plancherel formula, Dirichlet's Theorem: A little elementary number theory, Dirichlet's theorem, Proof of the theorem.

			Course References: E. M. Stein and R. Shakarchi: Fourier analysis: An Introduction.
MTH206M	MATRIX ALGEBRA AND LINEAR ESTIMATION (MODULE I)	3-1-0-0-6	Review of finite dimensional Vector Spaces Vector spaces - Subspace - Linear independence - Basis and dimension Sum, direct sum and complement of subspaces Orthogonality and orthogonal basis - orthogonal complement; Matrix Algebra Preliminaries Different types of matrices - Operations of matrices - Properties of operations; Rank of a Matrix Row space and column space Rank - Results related to ranks of matrices; Determinant and Inverse of a non-singular matrix Inverse of a matrix - Properties of inverse Elementary matrix operations - Different matrix forms Determinant - Properties of determinant. Solution of Linear Equations Homogeneous systems - General linear systems Sweep out method for solving linear systems. Eigenvalues and vectors, Spectral and Singular value decomposition Characteristic roots - Eigenvectors and eigenspaces Spectral decomposition of a semi-simple matrix Singular value decomposition. Real quadratic forms, Reduction of pair of real symmetric matrices, Extrema of quadratic forms Classification of quadratic forms - Rank and signature Definiteness of matrices - Extrema of quadratic forms
MTH207M	MATRIX ALGEBRA AND LINEAR ESTIMATION (MODULE II)	3-1-0-0-6	Recap of important topics/results from Module I. Generalised Inverses, Moore-Penrose Inverse. Left and right inverses of a matrix – G-inverse, Minimum Norm and Least Squares g-Inverse, Moore-Penrose inverse. Projection and Orthogonal Projection Matrices: Projection and projection matrices - orthogonal projection, Properties of projection and orthogonal projection matrices. Vector and Matrix Differentiation: Basic idea of matrix differentiation, differentiation of linear and quadratic forms, determinants, Inverse of a matrix - maxima, minima of functions of several variables. Linear Model and Least Squares Theory of Estimation: Introduction to linear model and basic assumptions, The Least Squares theory of estimation - Properties of Least Squares Estimators. Estimability of a Linear Parametric Form: Non full column rank design matrix, Unbiasedly estimable Linear Parametric functions. Gauss-Markov Theorem and Best Linear Unbiased Estimator: Class of Linear Unbiased Estimators and the Best Linear Unbiased Estimator, The Gauss-Markov Theorem. Fisher-Cochran Theorem (matrix theoretic version) through some properties of the idempotent matrix. Estimation under restriction: Least Squares estimation under a set of restrictions on linear parametric functions.
MTH208	DATA SCIENCE LAB 1	0-0-3-2-5	The courses focuses on fundamental computational learning base for modern data analysis. Introduction to Programming for Data Science -- Python, R, Rstudio, text editors, Google colab, RMarkdown, and RShiny. Introduction to git. Web scraping. Data cleaning and wrangling for numeric and non-numeric data. Standard statistical visualizations. Data and code reproducibility. Interfacing R, C++, and Python. Ethics

			and bias in data collection, including statistical paradoxes, data ethics, social biases in data, statistics in the media.
MTH209	DATA SCIENCE LAB 2	1-0-2-0-5	Computational implementations of linear algebra (Gauss elimination method, determinants, eigenvalues, eigenvectors, matrix decompositions, generalized inverses, computational complexity of matrix operations). Practical parallel computing, computational tools for optimization and implementation of least squares. Computational implementations of drawing samples, density functions, mass functions, summary functions, numerical integration for expectations. Copula functions, contour plots in two and higher dimensions. Dimensionality reduction for data visualization using ideas like PCA, LDA, TSNE and UMAP. Demonstrate probability inequalities, and the weak law of large numbers. Simulations for the central limit theorem.
MTH210	STATISTICAL COMPUTING	3-0-1-0-10	Pseudorandom number generation, generating random variables (discrete and continuous) -- inverse transform, accept-reject, Box-Muller transformation, ratio-of-uniforms. Importance sampling (simple and weighted). Review of optimization, duality and KKT conditions. Newton-Raphson, gradient ascent, coordinate ascent. Least squares and optimization -- linear regression, ridge, lasso, bridge. Logistic regression, least angle regression. Crossvalidation and bootstrap. MM and EM algorithm, mixture of Gaussians. Non-convex optimization, stochastic gradient ascent, simulated annealing. Bayesian models and Metropolis-Hastings.
MTH211	THEORY OF STATISTICS	3-1-0-0-11	Descriptive Statistics: Population and sample notions, Methods of sampling: Simple random sampling with (and without) replacement, stratified sampling, Types of data: categorical, continuous, ordinal, nominal, Visualizing (univariate and multivariate): boxplots, histogram, stem-leaf plot, bar graph, ogive, scatterplot, side-by-side boxplot, starplot; Measures of Central Tendency: Means (arithmetic, geometric, harmonic), median, mode; Measures of Dispersion: Variance, interquantile range, Mean absolute deviation, standard deviation, Skewness, kurtosis, coefficient of variation, sample \$r\$th moment and raw moments; Measures of association: Correlation, Kendall's \$\tau\$, Spearman rank correlation; Point Estimation: Statistic, estimators, Sufficiency, completeness, unbiasedness, UMVUE, Information inequalities, Cram{\'e}r-Rao lower bound, Methods of estimation: maximum likelihood estimator, method of moments, Properties of MLE and MoM; Testing of Hypothesis: Null and alternative hypothesis, simple and composite hypothesis, size, power, Neyman-Pearson lemma for simple vs simple and its use for testing composite hypothesis, UMP test, likelihood ratio tests; Confidence Interval: Pivotal statistics, methods of constructions; Bayesian statistics: Basics, point estimation as a decision problem, Prior dist, Bayes risk, Bayes estimators under losses, credible sets
MTH212M	ELEMENTARY	3-1-0-0-6	Definition and classification of general stochastic processes,

	STOCHASTIC PROCESSES I		Markov Processes and Markov Chains: Definition and classification of Markov processes, Definition of Markov Chains of Order r (focus on Order 1), and corresponding Transition Probability Matrices, Examples - Gambler's Ruin, Random Walk etc., Chapman-Kolmogorov equations, Derivation of higher order transition probabilities from 1-step transition probabilities. Classification of States: Accessible, Absorbing and Communicating states, Communication as an equivalence relation, Irreducible Markov Chains, Recurrent and Transient states (focus on the probability of visiting a state infinitely often, through Borel-Cantelli Lemma), Effect of dimension on a Markov chain: compare through Random Walks on 1, 2 and 3 dimensions; Finite Markov chains, properties of finite irreducible Markov Chains, Periodic States, Closed sets, Communicating class properties, absorption in closed sets, Limiting behaviours: Null and Positive Recurrence, Ergodicity; Stability of Markov Chains, Limiting distributions, Stationary distributions
MTH215	AN INTRODUCTION TO NUMBER THEORY	3-1-0-0-11	Divisibility, Primes, fundamental theorem of arithmetic, Euclidean algorithm, Congruence and modular arithmetic, Chinese remainder theorem, Roots of unity, Quadratic reciprocity, Binary quadratic forms, Some Diophantine equations, Some arithmetic functions, Distribution of prime numbers, Bertrand’s postulate, the partition function, Dirichlet Series, Riemann Zeta function.
MTH301	ANALYSIS - I	3-1-0-0-11	Real Number system: Completeness property. Countable and Uncountable Metric Spaces: Metric spaces, Examples: l_p , C[a; b]; Limit, Open sets, Convergence of a sequence, Closed sets, Continuity. Completeness: Complete metric space, Nested set theorem, Baire category theorem, Applications. Compactness: Totally bounded, Characterizations of compactness, Finite intersection property, Continuous functions on compact sets, Uniform continuity. Connectedness: Characterizations of connectedness, Continuous functions on connected sets, Path connected. Riemann integration: Definition and existence of integral, Fundamental theorem of calculus, Set of measure zero, Cantor set, Characterization of integrable functions. Convergence of sequence and series of functions: Pointwise and uniform convergence of functions, Series of functions, Power series, Dini's theorem, Ascoli's theorem, Continuous function which is nowhere differentiable, Weierstrass approximation theorem. Reference materials: 1. N. L. Carothers, Real Analysis. 2. R. R. Goldberg, Methods of Real Analysis. 3. W. Rudin, Principles of Mathematical Analysis.
MTH302	SET THEORY & LOGIC	3-1-0-0-11	Some basics of set theory: Relations, Partitions, Functions and sets of functions. Families of sets, Cartesian products of families. Principles of weak and strong mathematical induction and their equivalence. Schroder-Bernstein theorem. Countable and uncountable sets. Cantor's theorem. Classical propositional calculus (PC):

			Syntax. Valuations and truth tables, Truth functions, Logical equivalence relation. Semantic consequence and satisfiability. Compactness theorem with application. Adequacy of connectives. Normal forms. Applications to Circuit design. Axiomatic approach to PC: soundness, consistency, completeness. Other proof techniques: Sequent calculus, Computer assisted formal proofs: Tableaux. Decidability of PC, Boolean algebras: Order relations. Boolean algebras as partially ordered sets. Atoms, Homomorphism, sub-algebra. Filters. Stone's representation (sketch). Completeness of PC with respect to the class of all Boolean algebras. Classical first order logic (FOL) and first order theories, Syntax. Satisfaction, truth, validity in FOL. Axiomatic approach, soundness. Computer assisted formal proofs: Tableaux. Consistency of FOL and completeness (sketch). Equality. Examples of first order theories with equality. Peano's arithmetic. Zermelo-Fraenkel axioms of Set theory. Axiom of choice, Well-ordering theorem, Zorn's lemma and their equivalence; illustrations of their use. Well-ordering principle and its equivalence with principles of weak and strong induction. Elementary model theory: Compactness theorem, Löwenheim-Skolem theorems. Completeness of first order theories, Isomorphism of models, Categoricity-illustrations through theories such as those of finite Abelian groups, dense linear orders without end points and Peano's arithmetic. Statements of Gödel's incompleteness theorems and un-decidability of FOL. Course references: 1. J. Bridge: Beginning Model Theory: The Completeness Theorem and Some Consequences. Oxford Logic Guides, 1977. 2. I. Chiswell and W. Hodges: Mathematical Logic. Oxford, 2007. 3. R. Cori and D. Lascar: Mathematical Logic, Oxford, 2001. 4. J. Goubalt-Larrecq and J. Mackie: Proof Theory and Automated Deduction, Kluwer, 1997. 5. P. R. Halmos: Naive Set Theory, Springer, 1974.
MTH303	A COURSE IN NUMBER THEORY AND CRYPTOGRAPHY	3-1-0-0-11	Some Topics in Elementary number theory: Complexity of Computation & Complexity Classes, time estimates of doing arithmetic, divisibility and the euclidean algorithm, prime, finite abelian group, congruences modulo n, the Chinese remainder theorem, computing inverse and huge powers. Finite fields and quadratic residues: Finite fields, Group of units in finite fields, quadratic residues and reciprocity. Cryptography: Some simple cryptosystems, enciphering matrices. Public key: The idea of public key cryptosystem, Choice of the public key, RSA, Attacks on RSA and remedies, discrete log, knapsack, Zero-knowledge protocols and oblivious transfer.

			Primality and factoring: The rho method, Fermat factorization and factor bases, the continued fraction method, the quadratic sieve method, pseudoprimes, fermat primality test, Miller-Rabin primality test, Solovay-Strassen primality test, AKS primality test. Elliptic curves: The definition and basic facts, The group structure on an elliptic curve, Integer factorization using elliptic curves, elliptic curve primality test, elliptic curve cryptosystem, elliptic curves over rational numbers.
MTH304	TOPOLOGY	3-1-0-0-11	Pre-requisite: MTH 301 Topological spaces; open sets, closed sets, basis, sub-basis, closure, interior and boundary. Subspace topology. Continuous maps, open maps, closed maps, Homeomorphisms. Product Topology. Hausdorff spaces, Countability and separation axioms. Compact spaces and its properties, Locally compact spaces, one point compactification, Tychonoff's Theorem, Statement and Applications of Urysohn Lemma, Tietz extension theorem and Urysohn metrization theorem. Connectedness, path connectedness, components, its properties. Quotient Topology, various type of examples, cone, suspension, surfaces as quotient spaces. Group actions, orbit spaces. Homotopy, Fundamental group, deformation retract, contractible spaces, simply connected spaces, computation of Π_1 (S^1), Π_1 (S^2), Brouwer fixed point theorem. Reference materials: 1. J. R. Munkres: Topology: A First Course, Prentice-Hall, 1975. 2. J. Dugundji: Topology, UBS, 1999. 3. M. A. Armstrong: Basic Topology, Springer. 4. G. F. Simmons: Introduction to Topology and Modern Analysis, Tata McGraw-Hill, 1963
MTH305	SEVERAL VARIABLE CALCULUS & DEFFERENTIAL GEOMETRY	3-1-0-0-11	Pre-requisite: MTH 301 Differentiation: Differentiable functions, Directional derivatives, Composition of differentiable functions and chain rule, Mean value inequalities. Inverse mapping theorem and Implicit mapping theorem. Regular value of differentiable maps, Lagrange multipliers. Higher order derivatives, Taylor’s Theorem. Curves: Definition and examples of regular curves in R^2 and R^3. Definition of parametrised curves. Arc length of a regular curve and arc length parametrisation of regular curves. Curvature of plane curves and Frenet-Serret formula for regular space curves. Statement of Green’s Theorem. Isoperimetric inequality for plane curves. Surfaces: Three equivalent definition of regular surfaces in R^3. Tangent planes. Differentiable functions on surfaces and differentiable maps between surfaces. Tangent Plane. Derivative of differentiable functions/maps on surfaces. First fundamental form. Local isometries. Gauss map, Weingartent map and second fundamental form. Principal curvatures, Gauss curvature and mean curvature of surfaces. Surfaces of revolution and classification

			of surfaces of revolution of constant curvature. Umbilic points on surface. Classification of totally umbilical surfaces. Hilbert's theorem on compact surfaces. Geodesics and examples. Reference materials: 1. Tom M. Apostol: Mathematical Analysis, Narosa Publishing House, India. 2. W. Rudin: Principles of Mathematical Analysis. 3. Spivak: Calculus on manifolds, Springer. 4. A Pressley: Elementary differential geometry, Springer India. 5. M P do Carmo: Differential geometry of curves and surfaces, Prentice Hall.
MTH308	NUMERICAL ANALYSIS AND SCIENTIFIC COMPUTING-I	3-0-1-0-10	Approximations in Scientific computing, Error propagation and amplification, conditioning, stability and accuracy, computer arithmetic mathematical software and libraries, visualization, linear systems- existence and uniqueness, sensitivity and conditioning, Gaussian elimination, special linear systems, iterative methods, nonlinear equations, convergence rates, non-linear equations in one dimension, system of non-linear equations, eigenvalue problems, existence and uniqueness, sensitivity and conditioning, computing eigenvalues and eigenvectors, approximation and interpolation, Hermite and Spline interpolation, piecewise polynomial interpolation, numerical differentiation and integration, Chebyshev differentiation and FFT, Richardson extrapolation. Course references: 1. M Heath: Scientific Computing – An introductory Survey. 2. Kendall E. Atkinson: An Introduction to Numerical Analysis. 3. S. D. Conte & S. de Boor: Elementary Numerical Analysis: An Algorithmic Approach. 4. J. Stoer and R. Bulirsch: Introduction to Numerical Analysis.
MTH309	PROBABILITY THEORY	3-1-0-0-11	Pre-requisite(s): MSO201/HSO 201 Limits of sequences of sets, σ-field of events. Probability measure, probability space. Random variables, induced probability space, probability distribution. Distribution function, decomposition theorem. Expectation and moments, inequalities. Various modes of convergence of sequences of random variables (in probability, almost surely, in r th mean). Convergence theorems for expectations of sequences of random variables (monotone convergence theorem, Fatou's lemma, dominated convergence theorem).Characteristic function and its properties, inversion formulae. Convergence of sequences of distribution functions, Helly-Bray theorems, convergence of moments. Independence of events and random variables, zero one laws. Convergence of series of independent random variables, Kolmogorov inequality, Kolmogorov three-series criterion, Khintchin's weak law of large numbers, Kolmogorov strong law of large numbers. Central limit theorems of Lindeberg-Levy, Liapounov and Lindeberg-Feller.

			Course references: 1. K.L.Chung: A Course in Probability Theory, Third Edition, Academic Press, 2001. 2. B.R.Bhat: Modern Probability Theory, Third Edition, New Age International (P) Ltd, 2004. 3. M. Loéve: Probability Theory-I, Graduate Text in Mathematics, Fourth Edition, Springer, 1977.
MTH312	DATA SCIENCE LAB 3	1-0-2-0-5	Prerequisites: MTH208, MTH209. The course covers analysis of a collection of datasets obtained from a variety of disciplines and applications. Every week, the goal will be to build a model and/or a prediction scheme to answer the questions pertaining to the field of application. Writing weekly reports and/or presentations will be an integral part of the course.
MTH313M	ELEMENTARY STOCHASTIC PROCESSES II	3-1-0-0-6	Prerequisites: MSO201/MSO205 Continuous time Stochastic Processes (focus on Counting process), Kolmogorov Consistency/Existence Theorem (statement only); Poisson Process (PP): Definition of a PP as a counting process, Alternative definition of a PP, Inter-arrival and Waiting times for a PP, Coupon Collector's problem, Order Statistics and PP, Non-homogeneous PP, properties involving the arrival times, Compound PP; Continuous time Markov Chains (Discrete State space) or Jump Markov Processes: Definition (focus on homogeneous Markov Chains), Examples: Birth and Death processes, Poisson Process as a Pure Birth process, M/M/c queues, Linear growth Models with immigration, Yule Process; Transition Probability function, Chapman-Kolmogorov equations (forward and backward), Limiting probabilities (may be an overview only, heuristic proof may be given with some motivation using the first module); Brownian Motion (BM): Definition of a BM, BM as a Markov process, Gaussian processes, Properties of a BM: Covariance function, Invariance properties, Path properties - using the Kolmogorov Continuity Theorem (statement only); Special topics (one of the following two topics to be covered): 1. Processes related to Brownian motion - Brownian bridge, Application of Brownian bridge in the study of empirical processes, Donsker's Invariance Principle (statement only), Stopping times, Hitting times, Strong Markov Property, Arc-Sine laws, Variants of BM: involving absorption and reflection, Geometric BM, Integrated BM, involving drift, 2. Branching processes: A little history of branching processes. The Galton-Watson Branching Processes (GWP). Probability generating function of GWP. Moment generating functions and moment calculations, Sub-critical, critical and super-critical scenario and the probability of extinction. Examples. Introduction to Continuous time Markov Branching Processes, Examples of Continuous time Markov Branching Processes – revisit to Yule Process or Binary Fission, Birth & Death Process. Generating functions. Sub-critical, critical and super-critical scenarios.

MTH314	MULTIVARIATE ANALYSIS	3-0-1-0-10	Prerequisites: MTH211/MTH418 Basic properties of random vector: CDF and PDF of random vectors – Moments – Characteristics functions, Orthogonal and Polar transformations, Generalization of univariate distribution (Multinomial, Dirichlet). Normal Distribution Theory: Normal data matrix (NDM): characterization and properties Linear forms – Transformation of NDMs, Wishart Distribution, The Hotelling's T2 Distribution; Estimation and Testing: Maximum likelihood estimation, Likelihood ratio test – Union intersection test, Simultaneous confidence intervals.; Multivariate Analysis of Variance (MANOVA): Formulation of multivariate one-way classification, Likelihood ratio principle; Principal Component Analysis: Principal components – Sampling properties of principal components – Principal component projections.; Factor Analysis: The factor model – Principal factor analysis – Maximum likelihood factor analysis – Goodness of fit – rotation of factors – factor scores; Canonical correlation analysis: Population and sample canonical correlation vectors, variables and coefficients and their properties.; Discrimination Analysis: Fisher's LDA -QDA – Probabilities of misclassification; Cluster Analysis:Distances and similarities -- Hierarchical methods – K-means method; Project presentations
MTH321	INTERNSHIP I	0-0-0-9-9	INTERNSHIP I (Only for BS Statistics and Data Science students)
MTH322	INTERNSHIP II	0-0-0-9-9	INTERNSHIP II (Only for BS Statistics and Data Science students)
MTH323	INTERNSHIP III	0-0-0-9-9	INTERNSHIP III (Only for BS Statistics and Data Science students)
MTH324	INTERNSHIP IV	0-0-0-9-9	INTERNSHIP IV (Only for BS Statistics and Data Science students)
MTH325	INTERNSHIP V	0-0-0-9-9	INTERNSHIP V (Only for BS Statistics and Data Science students)
MTH401	THEORY OF COMPUTATION	3-0-0-0-9	Regular languages, Deterministic and nondeterministic nite automata, Closure properties, Languages that are and are not regular, State minimizationin deterministic nite automata. Contextfree languages, Closure properties, Parsetrees, Languages that are and are not contextfree, Pushdown automata. Turing machines, Turing computability, ChurchTuring thesis, Halting problem, Some undecidable problems. Computational complexity, Classes P and NP, NPcompleteness, Examples of NPcomplete problems. **Course Reference**: 1. H.R. Lewis and C.H. Papadimitriou: Elements of the Theory of Computation, PrenticeHall, 1998; 2. J.E. Hopcroft, R. Motwani, J.D. Ullman, Introduction to Automata Theory, Languages, and Computation, Pearson Education, 2001.
MTH403	COMPLEX ANALYSIS	3-1-0-0-11	Topology on C, Convergence and continuity. Cauchy Riemann equation, Elementary Functions. Power series: Convergence, Exponential, Trigonometric functions.

			Integration along curves, CauchyGoursat Theorem, Cauchy's theorem for disc, Evaluation of some integrals, Cauchy integral formula, Liouville theorem and fundamental theorem of Algebra, Identity theorem, Morera's theorem. Zeros and poles, Residue theorem, Evaluation of some integrals. Riemann theorem on removable singularities, Essential singularities, Casorati Weierstrass theorem. Riemann sphere, Argument principle, Rouche's theorem, Open mapping theorem, Maximum modulus principle, Cauch's theorem for simply connected domain, Analyticity of complex logarithm. Harmonic functions, Poisson integral formula, Characterization of harmonic functions through MVP.Fractional linear transformation, Schwartz lemma, Pick's lemma, Automorphisms of discand upper half plane. Montel theorem, Riemann mapping theorem. **Course Reference** :1. Stein and Shakarchi: Complex Analysis, Princeton Lect. in Analysis; 2. Gamelin: Complex Analysis, Springer
MTH404	ANALYSIS II	3-1-0-0-11	Lebesgue measure on Rn: Introduction, outer measure, measurable sets, Lebesgue measure, regularity properties, a nonmeasurable set, measurable functions, Egoroffs theorem, Lusins theorem. Lebesgue integration: Simple functions, Lebesgue integral of a bounded function over a set of finite measure, bounded convergence theorem, integral of nonnegative functions, FatousLemma, 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, Lpspaces: The Minkowskis inequality and Hlders inequality, completeness of Lp, denseness results in Lp. Fourier series: Definition of Fourier series, formulation of convergence problems, The L2 theory of Fourier series, convergence of Fourier series.
MTH405	FUNCTIONAL ANALYSIS	3-1-0-0-11	Fundamentals of normed linear spaces: Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Bounded linearmaps on a normed-linear spaces: Examples, linear map on finite dimensional spaces, finite dimensional spaces are isomorphic, operator norm. HahnBanach 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 anoperator. Hilbert spaces: Inner product spaces, orthonormal set, GramSchmidt orthonormalization, Bessels 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.
MTH409	COMPUTER PROGRAMMING AND DATA STRUCTURES	2-1-1-0-9	Fortran 77: Integer and real operations, logic and complex operations, Controlstatements, Do statement, arrays subroutines and functions. Introduction todata structures in C Programming Language; Arrays: linear, Multidimensional, Records, Pointers, Stacks, queues, Linked Lists; Singly linked lists, doubleedlinked lists, circular linked lists, Application of Linked Lists; Polynomial addition, sparse matrices, Trees: binary trees, redblack trees, Hash tables. somediscussion about data structures in F90F95 with examples. 21-JUL-2014
MTH418	INFERENCE I		Parametric models, parametrs, random sample and its likelihood, statistic andits 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, RaoBlackwell theorem, CramerRao lower bond, different examples. Statistical Hyptheses simple and composite, statistical tests, critical regions, TypeI and TypeII errors, size and power of a test, Neyman Pearson lemma and its different applications. Most powerful test, uniformly most powerful test, unbiased testand 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.
MTH421	ORDINARY DIFFERENTIAL EQUATIONS	3-1-0-0-11	Introduction to ODE; Existence and uniqueness of solution; Continuityand dierentiability of solution w.r.t. initial condition and parameters; General theory of linear dierential equations; Methods of solving nonhomogeneous linear equations; CauchyEuler equation; Linear equations with periodic coecients; System of lineardierential equations; Stability theory for system of linear dierential equations; StrumLiouville boundary value problems, Oscillation theory; Green's function. **Course Reference**: 1. Martin Brown, Dierential Equations and Their Applications, Springer, 1992; 2. S. L. Ross, Introduction to Ordinary Dierential Equations, Wiley, 1980; 3. Deo, Lakshmikantham, Raghavendra, Textbook of Ordinary Dierential Equations, Tata McGraw Hill, 1997; 4. C. Y. Lin, Theory and Examples of Ordinary Dierential Equations, World Scientic,2011.
MTH422	AN INTRODUCTION TO	3-0-1-0-10	A brief review of probability theory: Univariate probability distributions, multivariate probability distributions , conditional distributions ; Introduction to Bayes: Bayes'

	BAYESIAN ANALYSIS		theorem and Bayesian learning , Frequentist versus Bayesian , problem set discussion ; Posterior summarization: Univariate posterior summarization , multivariate posterior summarization , posterior predictive distribution , problem set discussion ; Conjugate priors: Importance of conjugate priors, derivation of the posteriors for a few univariate and multivariate discrete distributions in case of conjugate priors , derivation of the posteriors for a few univariate continuous distributions in case of conjugate priors , derivation of the posteriors for univariate and multivariate normal distribution in case of conjugate priors ; Prior elicitation and objective priors: Prior elicitation, mixture priors, and Jeffreys' priors , other objective priors , problem set discussion ; Bayesian Computations: Deterministic computations , Gibbs sampling , Metropolis-Hastings sampling , MCMC convergence diagnostics ; Essential softwares: R essentials for Bayesian computing , JAGS essentials for Bayesian computing ; Bayesian linear models: Bayesian hypothesis testing, one-sample and two-sample t-tests , Bayesian linear regression (BLR) including Bayesian LASSO , Implementation of BLR using R-JAGS , Bayesian generalized linear models (GLMs) and random-effects models (REMs) , Implementation of Bayesian GLMs and REMs using R-JAGS , Nonparametric Bayesian regression with R-JAGS illustrations ; Bayesian model comparison: Bayes factor, Stochastic search variable selection, Bayesian model averaging , Crossvalidation (CV), K-fold crossvalidation (K-CV), Some information criteria including DIC and WAIC , R-JAGS implementation of CV, K-CV, DIC, and WAIC , Posterior predictive checks ; Bayesian hierarchical models: Building a hierarchical model through layers and its analogy with Directed acyclic graphs , Missing data handling in Bayesian models ; Case study demonstration: Illustation of Bayesian hierarchical models for analyzing real datasets; Big data: Frequentist properties of Bayesian methods: Decision theory and Bias-variance tradeoff , Asymptotics and simulation studies Lab component: Probability distributions in R: Univariate and multivariate probability distributions-related functions and additional R packages; Introduction to Bayes using R: Implementation of simple Bayesian learning examples using R; Posterior summarization using R: Univariate and multivariate posterior summarization and evaluating posterior predictive distributions using simulation and numerical integration in R; Conjugate priors using R: Part 1 - Examples of the posteriors for a few univariate distributions in case of conjugate priors; Conjugate priors using R: Part 2 - Examples of the posteriors for a few multivariate distributions in case of conjugate priors; Objective priors using R: Summarizing posterior distributions in case of objective priors, prior elicitation; Deterministic computations using R: Numerical integration, Gaussian approximation of the posterior distribution and

			related computations using R; Gibbs sampling using R: Examples of Gibbs sampling using R; Metropolis-Hastings sampling using R: Examples of Metropolis-Hastinsg sampling using R; JAGS implementations: Implementation of the same examples using JAGS; MCMC convergence diagnostics: MCMC convergence diagnostics using R-JAGS; Model comparison: K-CV, DIC, and WAIC; Hierarchical models: Implementation of hierarchical models using R-JAGS
MTH423	INTRODUCTION TO CONTINUUM MACHANICS	3-1-0-0-11	Fundamental concepts; Introduction to Cartesian tensors; Stress tensors and equilibrium equations; Theory of strain and rate of deformation tensor; Conservation laws and basic equations; Linear Elasticity {Hooke's law, plane elasticity, Airy's stress principle, Torsion and bending; Fluid mechanics} Incompressible inviscid flow, Incompressible viscous flow, Introduction to boundary layer theory **Course Reference**: 1. Introduction to Continuum Mechanics {M. Lai, D. Rubin, E. Krempl}; 2. Continuum Mechanics for Engineers {G. T. Mase and G. E. Mase}; 3. Elementary fluid mechanics {D. J. Acheson}; 4. Fluid Mechanics {P K Kundu and I M Cohen}; 5. Mathematical Theory of Elasticity {Sokolniko}
MTH424	PARTIAL DIFFERENTIAL EQUATIONS	3-1-0-0-11	Introduction to PDEs, First order quasilinear and nonlinear equations; Higher order equations and classications; Solution of wave equations, Duhamel's principleand applications; Existence and uniqueness of solutions; BVPs for Laplace's and Poisson's equations, Green's function, Maximum principle for the Laplace equation; Heat equation, Maximum principle for the heat equation, Uniqueness of solutions of IVPs forheat conduction equation. **Course Reference**: 1. Robert C. McOwen: Partial Dierential Equations, Pearson Education Inc; 2. Alen Jerey: Applied Partial Dierential Equations, Academic Press; 3. Ervin Kreyszig: Advanced Engineering Mathematics, John Wiley & Sons; 4. T. Amarnath, An Elementary Course in Partial Dierential Equations, Narosa Publications.
MTH426	AN INTRODUCTION TO MATHEMATICAL MODELLING		What is a model? What is Mathematical modelling? Role of Mathematics in problem solving; Transformation of Physical model to Mathematical model with some illustrations of real world problems; Mathematical formulation, Dimensional analysis, Scaling, Sensitivity analysis, Validation, Simulation, Some case studies withanalysis (such as exponential growth and decay models, population models, Traffic flow models, Optimization models). Reference materials: 1. D. N. P. Murthy, N. W. Page and E. Y. Rodin: Mathematical Modelling: A Tool for Problem Solving in Engineering, Physical, Biological and Social Sciences, Pergamon 1990. 2. Clive L. Dyne: Principles of Mathematical Modeling, Academic Press, 2004. 3. R. Ilner, C. Sean Bohun, S. McCollum and T. van Roode: Mathematical Modeling: A case study approach, AMS 2004.

MTH428	MATHEMATICAL METHODS	3-1-0-0-11	Multiple Integral Theorems and their Applications: Greens theorem, Stokes theorem and Gauss divergence theorem. Integral Transforms: Fourier, Fouriersine/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, Legendres and Jacobis condition. Existence of solutions of variational problems. RayleighRitz method, statement of Ekelands variational principle; Self adjoint, normal and unitary operators; Banach algebras.
MTH430	NUMERICAL ANALYSIS & SCIENTIFIC COMPUTING II		Pre-requisite(s): MTH 308 Linear least squares problems, existence and uniqueness, sensitivity and conditioning, orthogonalization methods, SVD, Optimization, existence and uniqueness, sensitivity and conditioning, Newton's method, Unconstrained Optimization, Steepest descent, Conjugate gradient method, Constrained optimization (optional), Numerical solution to ODE, IVP: Euler's method, One step and linear multistep methods, Stiff differential equations, boundary value problems, Numerical solution to PDEs, review of second order PDEs: hyerbolic, parabolic and elliptic PDEs, Time dependent problems, Time independent problems Reference material(s): 1. Michael Heath: Scientific Computing – An Introductory Survey. 2. K. E. Atkinson: An Introduction to Numerical Analysis. 3. S. D. Conte and C. de Boor: Elementary Numerical Analysis: An Algorithmic Approach. 4. J. Stoer and R. Bulirsch: Introduction to Numerical Analysis.
MTH432M	INTRODUCTION TO SAMPLING THEORY	3-1-0-0-6	Principles of sample surveys; Simple, stratified and unequal probability sampling with and without replacement; ratio, product and regression method of estimation, Varying Probability Scheme
MTH433	REAL ANALYSIS	3-1-0-0-11	Real numbers, sequences, series, tests for convergence, absolute convergence, rearrangement of terms. Open and closed sets. Continuous functions of one real variable. Differentiation. Riemann integration. Fundamental theorem of calculus. Computation of definite integrals. Improper integrals. Sequences of functions, and point-wise convergence. Uniform convergence; and its relation with continuity, differentiation and integration. Functions of several variables. Continuity. Partial derivatives. Differentiability. Taylor's theorem. Maxima and minima.

			Double integral, Fubini's theorem, Triple integration (evaluation). Course references: 1. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Wiley, 2011. 2.J. E. Marsden, A. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer, 1993. 3.T. M. Apostol, Calculus, Vols. 1 and 2, Wiley, 1991 and 1969.
MTH434M	COMPLEX ANALYSIS	3-1-0-0-6	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, Laurent series, Zeros, singularities, poles, essential singularities, Residue theorem and its Applications Course references: J. W. Brown and R. V. Churchill, Complex Variables and Applications, McGraw-Hill, 2004. 2. L. V. Ahlfors, Complex Analysis, McGraw-Hill, 1966
MTH436	BASIC ALGEBRAIC GEOMETRY	3-0-0-0-9	Curves and surfaces, Affine and projective varieties, Zariski topology, Hilbert Nullstellensatz, Bezout's theorem, Tangent space and smoothness, irreducibility and dimension, morphisms, Grassmannian and flag varieties, determinantal varieties, Normal varieties and Zariski's main theorem, Birartional Geometry and Resolution of singularity, Divisors and Riemann-Roch for curves.
MTH441	LINEAR REGRESSION AND ANOVA	3-0-1-0-10	Introduction to Simple and Multiple Linear Regression Models: Estimation of the parameters using least squares and maximum likelihood estimation methods and their properties; Topics on Multivariate Normal Distribution:a. Introduction to Multivariate Normal distribution, and basic properties, b. Distribution and independence of quadratic forms, c. Cochran's theorem.; Testing of Hypotheses and Confidence Intervals: a. General testing of $H: A\boldsymbol{\beta}={\bf c}$ all possible special cases. b. Goodness of fit test with introduction to R-square, etc. c. Interval estimation: Confidence band and prediction intervals, simultaneous confidence intervals/ellipsoid, Bonferroni's correction.; Residual Analysis and Regression Diagnostics: a. Detecting outliers: Different types of residuals, Hat matrix diagonals (in connection with leverage points), Detecting and dealing with outliers.b. Departures from underlying assumptions: diagnosis and remedies. (i) Dealing with curvatures, (ii) non-constant variance and serial correlation, (iii) Departures from normality.; Multicollinearity: a. Implication of multicollinearity. b. Diagnostics: VIF and Variance Decomposition Methods.c. Remedial measures: Canonical regression and principal component regression,

			Ridge Regression.; Variable Selection: a. Introduction to variable selection, under and over-fitting problems. b. Model selection: Adjusted R-square, Mallows Cp, , Cross-validation. c. Variable selection: Forward selection, Backward elimination, Stepwise variable selection. d. Penalized regression: AIC, BIC criteria.; Use of Categorical Explanatory or Dummy Variables:a. Indicator variables. b. Introduction to ANOVA and ANCOVA models. c. ANOVA table, splitting of sum of squares. d. Estimation and testing in the above setups.; Design preliminaries, CRD, RBD and LSD: a. Introduction and Principles of designs. b. CRD-Methodology and development of analysis of variance. c. RBD- Methodology and development of analysis of variance. d. LSD- Methodology and development of analysis of variance. Generalized Linear Models: a. Introduction to GLM: systematic and random components, link functions, b. Maximum Likelihood Estimation: iteratively re-weighted least squares, c. Applications: Logistic regression for binary data, Poisson regression for count data.;
MTH442	TIME SERIES ANALYSIS	3-0-1-0-10	Prerequisites: MTH211/MTH418 Introduction and preliminary tests of time series, Mathematical formulation of time series and stationarity concepts, ACVF and ACF of stationary time series and its properties, Linear stationary processes and their time domain properties-AR, MA, ARMA, Invertibility of AR, MA, ARMA; Auto covariance generating function; Multivariate time series processes and their properties-VAR, VMA, VARMA; Random sampling from stationary time series; Parameter estimation of AR, MA and ARMA models; Best Linear predictor and Partial auto correlation function (PACF); Model order estimation techniques, Spectral density, its properties and estimation; Spectral density function of stationary linear processeSpectral distribution function; Cross-spectrum for multivariate processes; Periodogram analysis. Lab component: Handling of time series datasets, Testing for existence of trend and seasonality and estimation, Computation of ACF, PACF, Modelling of univariate and multivariate time series, Model order estimation, Residual analysis, Periodogram analysis, Term project presentations
MTH443	STATISTICAL & AI TECHNIQUES IN DATA MINING	3-0-1-0-10	Prerequisites: MTH211 Introduction and preliminary concepts, Principal component analysis, Measures of similarity/dissimilarity, Cluster Analysis, Density estimation, Association rule mining, Discriminant Analysis & Classification, Statistical Modelling, Classification & Regression Trees, Artificial Neural Networks, Genetic Algorithm Lab component: Multidimensional feature vector visualization, Data projection, clustering and outlier detection, Implementation of variants of apriori algorithm for

			ARM, Kernel density estimation, Implementation of FLDF, QDF, Logistic, SVM; Tree based classifiers and random forest, Neural network model building, Term project presentations
MTH496	UNDER GRADUATE PROJECT I	0-0-0-9-9	UNDER GRADUATE PROJECT I
MTH497	UNDER GRADUATE PROJECT II	0-0-0-9-9	UNDER GRADUATE PROJECT II
MTH498	UNDER GRADUATE PROJECT III	0-0-0-9-9	UNDER GRADUATE PROJECT III
MTH499	UNDER GRADUATE PROJECT IV	0-0-0-9-9	UNDER GRADUATE PROJECT IV
MTH511	STATISTICAL SIMULATION AND DATA ANALYSIS	3-1-0-0-11	Simulation of random variables from discrete, continuous, multivariate distributions and stochastic processes, Monte Carlo methods. Regression analysis, scatterplot, residual analysis. Computer Intensive Inference 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.
MTH515	INFERENCE II	3-1-0-0-11	Group families; Principle of invariance and equivariant estimators- location family, scale family, location-scale family; General Principle of equivariance; Minimum risk equivariant estimators under location scale and location-scale families; Bayesian estimation; prior distributions; posterior distribution; Bayes estimators; limit of Bayes estimators; hierarchical Bayes estimators; Generalized Bayes estimators; highest posterior density credible regions; Minimax estimators and their relationships with Bayes estimators; admissibility; Invariance in hypothesis testing; Review of convergence in probability and convergence in distributions; consistent estimators; Consistent and Asymptotic Normal (CAN) estimators; BAN estimator; asymptotic relative efficiency (ARE); Limiting risk efficiency (LRE); Limiting risk deficiency (LRD; CRLB and asymptotically efficient estimator; large sample properties of MLE.
MTH516	NON-PARAMETRIC INFERENCE	3-1-0-0-11	Order statistics, Run tests, Goodness of fit tests, rank order statistics, sign test and signed rank test. general twosample problems, MannWhitney 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.
MTH520	NUMERICAL LINEAR ALGEBRA	3-1-0-0-11	Computer arithmetic. Vector and matrix norms. Condition number of a matrixand 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.
MTH522	FINITE ELEMENT METHOD	3-1-0-0-11	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, Constructionof FE spaces, Polynomial approximation theory in Sobolev spaces, Variational problem for second order elliptic operators and approximations, Mixed methods, Iterative techniques.
MTH523	FLUID MECHANICS	3-1-0-0-11	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.
MTH524	ALGORITHMS	3-1-0-0-11	Preliminaries: Introduction to algorithms; Analyzing algorithms: space and time complexity; growth of functions; summations; recurrences; sets, etc. Greedy Algorithms: General characteristics; 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: Representation 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.
MTH525	ELLIPTIC CURVES, MODULAR FORMS AND CONGRUENT NUMBER PROBLEM	3-0-0-0-9	Congruent numbers: definition, example, history, basic results and relation with elliptic curves, Some basics of projective geometry and algebraic curves, Elliptic curves over complex numbers, Elliptic curve in Weierstrass form, group law of elliptic curves, Elliptic curves over finite fields, Congruent elliptic curve, points of finite order, Hasse-Weil L-function of an elliptic curve, functional equation for the L-function of a congruent elliptic curve, Modular forms: action of on upper half plane, fundamental domain, modular forms for and congruence subgroups, Eisenstein series, cuspforms, Ramanujan Δ-function, Hecke operators, eigenforms, L-function of a modular form, 1/2 integral weight modular forms, definition and examples, Θ-function, Statement of Coates-Wiles theorem, Shimura's correspondence, Tunnel's criterion for congruent number, Heegner points.
MTH598	PROJECT- I	0-0-0-9-9	M.Sc project I
MTH599	PROJECT- II	0-0-0-9-9	M.Sc project II

MTH600M	INTRODUCTION TO PROFESSION AND COMMUNICATION SKILLS (MATHEMATICS)	3-0-0-0-5	(1) In the first three weeks of the course two lectures, each of one and half hour duration, every week are given by faculty members on a fundamental topic in Mathematics. (2) In the remaining weeks, students should present a topic in Mathematics of their choice. Their talk should contain mathematical concepts, and some proofs. Students can make their presentations individually or in pairs.
MTH603	MATHEMATICAL MODELLING	3-0-0-0-9	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.
MTH606	BIOMATHEMATICS	3-0-0-0-9	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 dynamicsand epidemics.
MTH611	ALGEBRA II	3-0-0-0-9	Fields: Definition and examples, Irreducibility Criterions, Prime Subfield, Algebraic and transcendental elements and extensions, Splitting field of a polynomial. Existence and uniqueness of algebraic closure. Finite fields, Normal and separable extensions, Inseparable and purely inseparable extensions. Simple extensions and the theorem of primitive elements, Perfect fields.Galois Extension and Galois groups. Fundamental theorem of Galois Theory. Applications of Galois Theory: Roots of unity and cyclotomic polynomials, Wedderburn's and Dirichlet's theorem. Cyclic and abelian extensions, Fundamental Theorem of Algebra, Polynomials solvable by radicals, Symmetric functions, Ruler and compass constructions. Traces and norms, Hilbert's theorem-90, Dedekind's theorem of Linear Independence of Characters. Inverse Galois Problem.(**Time permitting**: Simple transcendental extension and Luroth's theorem. Infinite Galois Extension and Krull's theorem.)
MTH612	INTRODUCTION TO COMMUTATIVE ALGEBRA	3-0-0-0-9	Review of basic notions of Rings and Modules, Noetherian and Artinian Modules, Exactness of Hom and tensor, Localization of rings and modules, Primary decomposition theorem, Integral extensions, Noether normalization and Hilbert Nullstellensatz, Going up and Going down theorem, Discrete Valuation rings and Dedekind domains, Invertible modules, Modules over Dedekind domain, Krull dimension of a ring, Hilbert polynomial and dimension theory for Noetherian local ring, Height of a prime ideal, Krull's principal ideal theorem and height theorem. Completions.
MTH613	RINGS AND MODULES	3-0-0-0-9	Review of Basic Ring theory: Integral domain and field of Fraction, Prime Avoidance theorem, Unique factorization domain, Principal Ideal domain, Euclidean domain, Gauss lemma, Polynomial Rings, Power series ring, Group ring, Modules: Vector spaces, Definition and examples of modules, Free modules, submodules and quotient modules, isomorphism theorems, Direct sum and direct products, Nakayama lemma, Finitely generated modules over a PID

			and applications, Rational Canonical form, Smith normal form, Jordan Canonical form, Jordan-Holder series, Projective and Injective Modules, Semi-simple rings and Modules, The Artin-Wedderburn theorem, Noetherian rings and Modules, Artinian rings and Modules, Hilbert basis theorem. (**Time permitting**: Artinian local rings and structure theorem of Artinian rings, Tensor products and multilinear forms, Exterior and Symmetric Algebra, Direct and Inverse system of modules.)
MTH614	INTRODUCTION TO STOCHASTIC CALCULUS	3-0-0-0-9	Preliminaries: σ-fields, random variables, Expectation, L^p spaces with respect to Probability measures, Conditional Probability and Conditional Expectation, Brownian motion: Definition, Construction/Proof of existence, path properties and Martingale property, Martingale Representation Theorem (If time permits), Stochastic Differential Equation: various notions of solutions, existence and uniqueness results, Application to Mathematical Finance: Black-Scholes formula.
MTH615	RIEMANN SURFACES	3-0-0-0-9	General theory of two dimensional manifolds, orientable surfaces, homology and cohomology of surfaces, Riemann surfaces, line bundles and vector bundles, Riemann-Roch theorem, Riemann bilinear relations, Abel-Jacobi map, Torelli's-theorem and Theta divisors.
MTH616	THEORETICAL NUMERICAL MATHEMATICS	3-0-0-0-9	The course content is divided into three parts. While the First part focuses on the approximation of functions, the other two deal with material related to the solution of linear and non-linear operator equations. The course will broadly cover the following topics: I. Theory of Approximations: Metric Spaces, Linear Spaces, Normed and Banach Spaces, Inner product and Hilbert Spaces; Problems on the Best Approximation, Orthogonal Expansions and Fourier Series in a Hilbert Space; Chebyshev Polynomials and their properties, Some Extremal Polynomials II. Linear Operators and Functionals: Linear Operators in Banach Spaces, Spaces of Linear Operators, Inverse Operators, Linear Operator Equations, Condition Measure of Operator; Spectrum and Spectral Radius of Operator, Convergence Conditions for the Neumann Series, Perturbations Theorem; Representation of Functions by Integrals; Linear Functionals and Adjoint Space, Adjoint, Selfadjoint, Symmetric Operators; Eigenvalues and Eigenelements of Selfadjoint and Symmetric Operators; Quadrature Functionals and Generalized Solutions of Operator Equations; Variational Methods, Variational Equations; Compact Operators; Sobolev Spaces, Generalized Solution of the Dirichlet Problem for Elliptic Equations of the Second Order III. Iteration methods for the solution of operator equations: General Theory of Iteration Methods; Chebyshev Iteration Methods, Descent Methods, Newton Method; Succesive Approximation Method for Inverse Operator; Stability and

			Optimization of Explicit Difference Schemes for Stiff Differential Equations
MTH617	INTRODUCTION TO COMPOSITION OPERATORS	3-0-0-0-9	Analytic functions, Möbius transformations, Fixed points, Classification of Möbius transformations, Self-maps of the unit disk, Hilbert spaces, Bounded operators, Adjoint of an operator, Functional Hilbert spaces, Reproducing kernels, Hardy space H^2, Growth estimate, Consequences, H^p spaces, Zeros, Blaschke products, Inner functions, Mean convergence theorem, Multiplication operators, Beurling's theorem, Invariant subspace problem, Equivalent conjecture, Composition operators, Introduction and motivation, Automorphic composition Operators, Littlewood's theorem, Norm estimates, Compact composition operators, Various compactness theorems, Compactness and Weak convergence, Compactness and Univalence, Angular derivatives and Iteration, Denjoy-Wolff theorem, König's theorem for eigen values, General compactness theorem, Introduction to various function spaces such as Bergman space, Dirichlet space and Bloch space and natural operators on them. Open problems.
MTH618	COMPLEX MANIFOLDS AND K\"AHLER GEOMETRY	3-0-0-0-9	Complex manifolds, Almost complex structures; Exterior forms on complex manifolds, Kähler metrics. ; Hodge theory for Kähler manifolds; Holomorphic vector bundles; Line bundles and divisors; Cohomology of holomorphic vector bundles; Vanishing Theorems and the Kodaira Embedding Theorem; Curvature of Kähler manifold; The Calabi Conjecture.; Riemann holonomy groups, The Kähler holonomy groups; Introduction to moduli spaces; Deformation theory for compact complex manifolds.
MTH620	MEASURE THEORY	3-0-0-0-9	Algebra, σ-algebra, measure, measurable functions, simple functions, integration, Fatou's lemma, monotone convergence theorem, Dominated convergence theorem, Riesz representation theorem, regular Borel measure, Lebesgue measure, L^p spaces, completeness of L^p and denseness results in L^p, signed and complex measures, Radon-Nikodym theorem, Lebesgue decomposition theorem, dual of L^p spaces, dual of $C_0(X)$, product measures, Fubini's theorem and its application, differentiation of measures.
MTH621	FOURIER ANALYSIS	3-0-0-0-9	Fourier transform on R^n, L^1 and R^n theory, Complex interpolation, R^n theory, Paley-Wiener theorem, Wiener-Tauberian theorem, Hilbert transform, Maximal function, real interpolation,Riesz transform, transference principle, Multipliers and Fourier Stieljes transform, Calderon-Zygmund singular integrals, Littlewood-Paley theory.
MTH624	DIFFERENTIABLE MANIFOLDS AND	3-0-0-0-9	Differentiable manifolds; Tangent space. Vector fields; Frobenius theorem; Relation between Lie subalgebras & Lie

	LIE GROUPS		subgroups; Cartans theorem on closed subgroups; One parameter subgroups, Exponential maps; Adjoint representation; Homogeneous spaces; Compact Lie groups; Symmetric spaces.
MTH627	APPLIED HARMONIC ANALYSIS	3-0-0-0-9	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
MTH628	TOPICS IN TOPOLOGY	3-0-0-0-9	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 FixedPoint Theorem.
MTH631	APPROXIMATION THEORY	3-0-0-0-9	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.
MTH632	SPECTRAL THEORY FOR SELF-ADJOINT OPERATORS	3-0-0-0-9	Unbounded Operators, Matrix representation, Self-adjointness Criterion, Quadratic Forms, Differential Operators, Self-adjoint Extensions, Functional Calculus, Spectra of Self-adjoint Operators, Semianalytic vectors, Theorems of Nelson and Nussbaum, States and Observables, Superselection Rules, Position and Momentum, An Uncertainty Principle of Bargmann, Canonical Commutation Relations, Schrodinger representations, Schrodinger Operators, Selfadjointness, A Theorem of Kato, Spectral Theory for Schrodinger Operators, Discrete Spectrum, Essential Spectrum **Course Reference**: 1. N. Akhiezer, I. Glazman, Theory of Linear Operators in Hilbert Space II, Dover, 1961; 2. J. Blank, P. Exner, M. Havlivcek, Hilbert Space Operators in Quantum Physics, Springer, 2008; 3. T. Kato, Perturbation Theory, Springer, 1976; 4. M. Miklavcic, Applied Functional Analysis and Partial Differential Equations, World Scientific, 1998; 5. M. Reed and B. Simon, Methods of Modern Mathematical Physics II, Academic Press, 1975.
MTH633	INTRODUCTION TO HYPERBOLIC GEOMETRY	3-0-0-0-9	Models of Hyperbolic Space: Upper Half Space Model & Disc Model; Isometries of Hyperbolic Space; Geodesics; Slimness of Triangles and Exponential Divergence of Geodesics in Hyperbolic Space; Isoperimetric Inequalities in Euclidean & Hyperbolic Space; Boundary of Hyperbolic Space; Review of Covering Spaces, Local Isometries and Fundamental groups; Properly Discontinuous Group actions; Fundamental Domains; Hyperbolic Surfaces
MTH634	BASES IN LOCALLY CONVEX SPACES AND KOETHE	3-0-0-0-9	Preliminaries, Elements of basis theory, Types of bases, Summability (summationof infinite series), Koethe sequence spaces, Bases in OTVS, Isomorphism theorems.

	SEQUENCE SPACES		
MTH635	AN INTRODUCTION TO OPERATOR THEORY	3-0-0-0-9	Introduction to Banach algebras: Gelfand Transform, commutative Banach algebras, Gelfand-Naimark Theorem, Spectral Theorem for normal operators and its applications to operators on a Hilbert space. The theory of Fredholm operators: spectral theory of compact operators (Fredholm Alternative). Operator matrices: Invariant and Reducing subspaces, the theory of ideals of compact operators (if time permits).
MTH636	GAME THEORY	3-0-0-0-9	Introduction: Examples of games, History of Game Theory, Intuitive definition of Game Theory; Normal form Games: Definition, Nash equilibrium, Notion of mixed strategies, Existence of Nash equilibrium in mixed strategies; Matrix Games: Two-player games, Zero-sum games, Min-max theorem, Non-zero sum games, Linear programming approach, Combinatorial Games: Definition, Examples, Zermelo's Theorem, Extensive form Games Notion of strategies (pure, mixed, and behavioural), Subgame perfect Nash equilibrium, Perfect Bayesian equilibrium, Sequential equilibrium; Other notions of Equilibrium: Iterative elimination of dominated strategies, Perfect equilibrium, Proper equilibrium, Strictly perfect equilibrium, Correlated equilibrium, A characterization of Nash equilibrium; Games under incomplete information: Definition, Static game under incomplete information, Bayesian Nash equilibrium, Signalling games, Auction; Repeated Games: Definition, subgame perfect Nash equilibrium, Folk Theorems, Advanced analysis of a class of Games: Cournot, Bertrand, Stackelberg, Sequential bargaining
MTH637	TOPICS IN OPERATOR THEORY AND HARMONIC ANALYSIS	3-0-0-0-9	L^p, R^n, Riesz Interpolation Theorem, Hilbert Transform, Hardy-Littlewood Maximal function, $H_1(R^n)$ and BMO, Distributions, Important example of distributions, Calderon-Zygmund Distributions.
MTH638	ABSTRACT HARMONIC ANALYSIS	3-0-0-0-9	Banach Algebras and Spectral theory, Locally compact groups, Basic representation theory, Analysis on Locally compact abelian group, Analysis on compact groups, Group C^*-algebra and structure of dual space.
MTH639	LOCALLY CONVEX SPACES	3-0-0-0-9	Topological linear spaces, Equicontinuity, Function spaces, Convexity & convex topological spaces, Hahn Banach theorem, Barrelled spaces, Principle of uniform boundedness, Bornological spaces, Duality theory (Mackey Arens Theorem, Mackey Topology, S-topology, Polarity).
MTH640	SEVERAL COMPLEX VARIABLES	3-0-0-0-9	Geometry of C^n: Reinhardt Domains: Definition and Examples, Absolute spaces. Elementary Theory of SCV: Holomorphic Functions: Definition and Examples, C-R Equations and its Applications. Power Series: Definition and Examples, Abel's Lemma and its Consequences, Complete Reinhardt Domains: Definition and Examples, Cauchy's

			Integral Formula for Poly-discs and its Consequences. Some New Phenomena in SCV: Biholomorphic Inequivalence of Unit Polydisc and Unit Ball, Zeroes of holomorphic functions are never isolated, Logarithmically Convex and Complete Domains: Definition and Examples, Hartogs' Phenomenon: Continuation on Reinhardt Domains. Singularities of Holomorphic Functions: Analytic Sets: Definition and Examples, Riemann Removable Singularity Theorems and its Applications, Hartogs' Kugelsatz, Zero Set of a Holomorphic Function: Topological Properties. Local Properties of Holomorphic Functions: Weierstrass Preparation Theorem, Weierstrass Division Theorem, Ring of Germs of Holomorphic Functions is Noetherian and an UFD, Local Parametrization for the Zero Set of a Holomorphic Function. Domains of Holomorphy: Domains of Holomorphy: Definition and Examples, Various Notions of Convexity: Definition and Examples, Logarithmically Convex Complete Domains as Domain of Convergence, Theorem of Cartan and Thullen.
MTH641	INTRODUCTION TO LIE ALGEBRAS AND REPRESENTATION THEORY	3-0-0-0-9	Definitions and first examples. Classical Lie algebras. Ideals and homomorphisms. Niporent Lie algegras. Engel's theorem. Solvable Lie algebras. Lie's theorem. Jordan Chevalley Decomposition. Radical and semisimplicity. The Killing form and Cartan's criterion. THe structure of semisimple Lie algebras. Complete reducibility and Weyls theorem. Representation theory of the Lie algebra sl(2). Total sub algebras and root systems. Integrality properties. Simple Lie algebras and irreducible root systems.
MTH642	TOPICS IN MODEL THEORY	3-0-0-0-9	The place of model theory in pure mathematics, Structures and homomorphisms: syntax, structures, homomorphism, isomorphism, substructure, embedding, examples. Semantics: evaluation of terms, satisfaction of formulas, elementary embedding, theory, elementary equivalence, examples. Compactness: Ultrafilters, product structures, ultraproducts, compactness theorem, applications, Lowenheim-Skolem theorem. Theories: dense linear orders (DLO), algebraically closed fields (ACF),real closed fields (RCF). Categoricity: definition, Vaught's test, back-and-forth method, Ryll-Nardzewski theorem, Morely's categoricity theorem. Quantifier elimination: explanation and characterization, Chevalley's theorem, Tarski-Seidenberg theorem. Types: definition, complete types, Stone spaces, omitting types theorem. Grothendieck ring: definable bijections, Grothendieck group of a monoid,Grothendieck ring of a structure, examples. Miscellaneous topics: Fraisse limits, imaginaries, geometries, model-completeness.
MTH643	SPATIAL STATISTICS	3-1-0-0-11	Examples of different types of spatial data and possible scientific questions: point-referenced data, areal data, point-pattern data; Review of multivariate statistical inference, Gaussian processes, Review of linear models, Review of matrix algebra; Spatial covariance and variogram, Estimation of variogram, Variogram model fitting, Spectral representation; Spatial regression and ordinary kriging, Robust kriging, Universal kriging, Simulation of spatial

			processes, R packages for data visualization and geostatistical modeling and applications of geostatistics; Some examples of areal datasets, conditional autoregressive models, simultaneous autoregressive models, Markov random fields; Gaussian maximum likelihood estimation and properties of the estimators; Point pattern data examples, Point referenced spatial data modeling: Inhomogeneous Poisson process, Cox process, Markov point process, Marked-Markov point process; Multivariate spatial and spatiotemporal modeling, Hierarchical spatial models for continuous and discrete responses, Remote sensing data analysis, Bayesian spatial models, Copula-based models, Large spatial data modeling, Nonstationary spatial modeling
MTH644	COMPLEX FUNCTION THEORY	3-0-0-0-9	Subharmonic Functions: Subharmonic Functions: Definition and Examples, Maximum Principles, Montel's Theorem for Harmonic Functions, Harnack's Inequality, Montel's Theorem for Positive Harmonic Functions. Dirichlet Problem: Dirichlet Problem for Bounded Domains, Dirichlet Problem for Disc and Punctured Disc, Peron Method, Harmonicity of the Peron Solution, Sub harmonic Barrier, Riemann Mapping Theorem, Uniformization Theorem for Riemann Sphere. Green's Functions: Green's Formulae, Green's Function for Unit Disc and Complex Plane, Harmonic Measure, Green's unction for Domains with Analytic Boundary, Green's Function for General Domains. Riemann Surfaces: Abstract Riemann Surfaces: Definition and Examples, Finite Bordered Surfaces, Analytic and Meromorphic Functions on Surfaces: Definition and Examples, Harmonic Functions on Surfaces, Maximum Principles. The Uniformization Theorem: Green's Function of a Surface, Existence of Green's Function for Finite Bordered Surfaces, Symmetry of Green's Function, Bipolar Green's Function, The Uniformization Theorem, Covering Surfaces.
MTH648	DIFFERENTIAL GEOMETRY	3-0-0-0-9	Differentiable manifold, Tangent Spaces, Submanifolds, Immersions, Embeddings, Vector Fields, Riemannian Metric, Examples: Euclidean Metric & Hyperbolic Metric, Isometries and Local Isometries, Isometries of upper half plane. Affine connection, Covariant Differentiation, Parallel Vector Field, Parallel Transport, Levi-Civita Connection, Christoffel Symbols. Geodesics, Geodesics Flow, Exponential Map, Gauss Lemma, Normal Neighborhoods, Minimizing Properties of Geodesics, Convex Neighborhoods, Geodesics inhyperbolic plane. Curvature, Bianchi Identity, Sectional curvature. Jacobi Field, Jacobi Equation, Conjugate Points. Geodesic complete manifold, Hopf-Rinow theorem, Cartan Hadamard Theorem.
MTH649	ALGEBRAIC TOPOLOGY	3-0-0-0-9	Recalling definition of homotopy and fundamental group. Van Kampen theorem.Free groups and Free product of groups. Fundamental groups of sphere, Wedgeof circles. CW-complexes definition and examples. Statement of classification of compact surfaces and polygonal representation. Computation of fundamental groups of compact surfaces. Homotopy extension property of a CW

			pair. Proof of the fact that if (X, A) has HEP and A contractible, then $X \to X/A$ is a homotopy equivalence. Examples from Hatcher. Covering spaces, Path lifting, homotopy lifting, general lifting. Examples of covering of wedge of circles, circles. Universal cover and existence of covering, classification of covering by subgroups of fundamental groups. Deck transformation,action of fundamental group on Universal cover, normal covering. Applications: Subgroup of free group is free, Cayley complexes. Homology: Singular homology; Theory (long exact, homotopy invariance and statement of excision, Mayer vietoris and computation for sphere, statement of Universal Coefficients Theorem) Applications: Degree of sphere and applications, homology and fundamental groups. CW homology, some computations of homology of projective spaces and surfaces, Euler characteristic and cells/ Betti numbers.
MTH651	INTRODUCTION TO TORIC VARIETIES	3-0-0-0-9	The course includes a review of basic results from algebraic geometric objects, such as algebraic varieties and their properties; Motivation and definition of a toric variety and some basic examples; Affine toric varieties and their explicit constructions; Rational convex polyhedral cones; Affine toric varieties derived from cones; Points on affine toric varieties; Normality and smoothness of toric varieties; Projective toric varieties and examples, Projective toric varieties from monomial maps; Convex lattice polytopes; Very ample and normal polytopes,; Normal fans; Projective toric varieties from polytopes; Gluing affine varieties and abstract toric varieties; Toric varieties from fans; Limits of one-parameter subgroups; Orbit-cone correspondence; Orbit closures as toric varieties; Toric morphisms; Background on divisors; Weil divisors on toric varieties; Cartier divisors on toric varieties; Line bundles on toric varieties; Homogeneous coordinates on toric varieties; the construction of a toric variety as a Geometric Invariant Theory (GIT) quotient.
MTH652	ADVANCED CALCULUS	3-0-0-0-9	Least upper bound principle; limits, monotone sequences; subsequences, Bolzano-Weierstrass, Cauchy sequences, completeness; countable and uncountable sets; convergence of series, conditional convergence; equivalence of completeness of $\mathbb{R};$; limsup, liminf, convergent series; absolute and conditional convergent, Riemann Rearrangement Theorem; convergence in $\mathbb{R}^n;$; open sets and closed sets on $\mathbb{R}^n;$ Cantor Intersection Theorem, Cantor set; limits and continuity; discontinuous functions; properties of continuous functions; uniform continuity; monotone functions; differentiation, Mean Value Theorem; Riemann integration; Fundamental Theorem of Calculus; sequence and series of functions, point wise convergence; uniform convergence, Weierstrass M-test,

			Dedekind test; uniform convergence and continuity; term by term integration and differentiation; power series; Taylor series, Weierstrass Approximation Theorem; analytic functions; Fourier series; differentiation of $f:\mathbb{R}^n \rightarrow \mathbb{R}^m$; partial derivatives; chain rule; higher derivatives, local extrema; Taylor expansion; multiple integrals, determinant and volumes, Jacobians.
MTH653	INTEGRAL EQUATIONS	3-0-0-0-9	Volterra and Fredholm integral equations, Resolvent Kernels. Operator equations, Fredholm theory, Hilbert Schmidt theory. Nonlinear integral equations, Singular integral equations.
MTH654	A COURSE IN OPERATOR THEORY	3-0-0-0-9	Spectrum, analytic functional calculus, square-root lemma, polar decomposition; Spectral theorem, Sturm-Liouville Theorem, Riesz-Schauder theorem, Fredholm Alternative; Ringrose-West decomposition, Volterra operators, singular values and canonical decompostion;Trace-class operators, trace ideals, Hilbert-Schmidt operators, Schur-Lalesco-Weyl inequality, Weyl's invariance theorem; The Hausdorff Moment Problem, Hausdorff Moment Theorem, Stieltjes and Hamburger moment problems, sufficient condition for determinacy; Orthogonal polynomials on the real line, Jacobi matrices, Favard's theorem, Bochner-Brenke Theorem
MTH656	SOBOLEV SPACES AND APPLICATIONS	3-0-0-0-9	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.
MTH657	GRAPH THEORY	3-0-0-0-9	Basic definitions. Blocks. Ramsey Numbers. Degree sequences. Connectivity.Eulerian and Hamiltonian Graphs. Planar graphs and 5 colour theorem. Chromatic numbers. Enumeration. MaxFlow MinCut Theorem. Groups and graphs. Matrices and graphs. Matchings and Halls Marriage Theorem. Eigen values of graphs.
MTH658	NONLINEAR DYNAMICAL SYSTEMS	3-0-0-0-9	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 viaLyapanov's direct method, Converse Lyapanov's theorems, Brokett's theorem,Applications to control system; Stable and unstable manifolds of equilibria, Stablemanifold theorem, HartmanGrobman theorem, Examples and applications,Center manifold theorem, Center manifold theorem, Normal form theory,Examples and applications to nonlinear systems and control; Poincare map, andstability theorems for periodic orbits; Elementary Bifurcation theory.
MTH659	NONLINEAR ANALYSIS AND ITS APPLLICATIONS TO PDE	3-0-0-0-9	Review of topic in functional analysis and Soblev space mapping between Banach spaces degree theory, Bifurcation theory. Variation Method: Constrained critical points, Deformation and Palais condition, Linking Theorems, Mountain Pass theorem and Ekeland Variation principal
MTH661	INTRODUCTION	3-0-0-0-9	Categorical preliminaries: category, morphisms, functor,

	TO SHEAVES AND TOPOS THEORY		natural transformation, universal constructions, adjoint functors, limits and colimits, exponentials. Functor categories: limits and colimits, subobject classifiers. Lattices and algebras: lattices, distributive lattices, implication, negation,Boolean algebra, Heyting algebra, subobject lattices in functor categories. Logic: interpretation of logical connectives in functor categories, quantifiers as adjoints. Sheaves on topological spaces: definition of sheaves, subsheaves, sieves,germ, stalk, bundles, cross-section, sheaves with algebraic structure, inverse image sheaves. Grothendieck topologies: generalized neighbourhood, sites, the Zariskisite, sheaves on a site, Grothendieck topos, associated sheaf functor. Properties of Grothendieck toposes: limits, colimits, exponentials, subobject classifier. Characterization of Grothendieck toposes: Elementary toposes, Giraud's theorem.
MTH662	CHEVALLEY GROUPS AND ALGEBRAIC GROUPS	3-0-0-0-9	Theory of bilinear forms on vector spaces over arbitrary fields, isometry groups, Lie structure on the tangent spaces of isometry groups, revision of Lie algebras, semisimple Lie algebras, Chevalley basis, Cartan-Weyl classification of semisimple Lie algebras, universal enveloping algebras, PBW, integral structures in Lie-algebras, construction of Chevalley groups, commutation relations, classification of Chevalley groups, automorphisms of Chevalley groups, introduction to elementary theory of schemes, Chevalley groups as algebraic groups, Borel subgroups, Tori, Root datum and classification of semisimple algebraic groups over algebraically closed fields.
MTH663	ANALYTICAL TECHNIQUES FOR PDE	3-0-0-0-9	Introduction to Semigroups, C0-semigroups, Hille-Yosida result, Heat equation, Wave equation, Inhomogeneous equations, Techniques for nonlinear problems, Palais-Smale Condition, Mountain Pass theorem, Hamilton Jacobi equations, Viscosity Solutions.
MTH664	TRIBOLOGY	3-0-0-0-9	The fundamentals of lubrication, friction & wear. Boundary lubrication, Hydrodynamic lubrication, Elasto hydrodynamic lubrication. Compressibility and thermal effects, Non-Newtonian lubrication, Roughness effects, Magneto hydrodynamic effects, Application to engineering & human systems.
MTH665	ASYMPTOTIC STATISTICS	3-0-0-0-9	Introduction Approximate Statistical Procedures; Asymptotic Optimality Theory Review of Stochastic Convergence Basic Theory, Stochastic and 0 Symbols, Characteristic Functions;

			AlmostSure Representations, Convergence of Moments, Convergence Determining Classes; Law of the Iterated Logarithm, Lindeberg Feller Theorem, Convergence in Total Variation Delta Method Basic Result, Variance Stabilizing Transformations; Higher Order Expansions, Uniform Delta Method; Moments M and Z Estimators Introduction; Consistency; Asymptotic Normality; Estimated Parameters, Maximum Likelihood Estimators, Classical Conditions, OneStep Estimators; Rates of Convergence; Argmax Theorem W. Contiguity Likelihood Ratios; Contiguity. Local Asymptotic Normality Introduction, Expanding the Likelihood Convergence to a Normal Experiment, Maximum Likelihood; Limit Distributions under Alternatives; Local Asymptotic Normality. Stochastic Convergence in Metric Spaces Metric and Normed Spaces; Basic Properties; Bounded Stochastic Processes. Empirical Processes Empirical Distribution Functions; Empirical Distributions; Goodness of Fit Statistics; Random Functions; Changing Classes; Maximal Inequalities Functional Delta Method von Mises Calculus; Hadamard Differentiable Functions; Some Examples Bootstrap Introduction, Consistency; Higher Order Correctness W.
MTH666	CATEGORY THEORY	3-0-0-0-9	Structure vs. property: monoids, groups, preorders, partial orders; structure preserving maps: homomorphisms, continuous maps; category; homsets and duality; functor covariant and contravariant; natural transformations.; Small, locally small and large categories; set theory vs category theory; Russell's paradox and the category of all categories; skeletons and axiom of choice.; Isomorphism; groupoid; monomorphism and epimorphism; full, faithful, essentially surjective functors, equivalence of categories; building even morecategories from the old ones: slice categories and local property, categories, functor categories, congruence and quotients.; Representable functors; Yoneda lemma and Yoneda embedding; separating anddetecting families; injective and projective objects; representables are projective.; Adjunctions: definition and examples; initial and terminal objects; relation to comma categories; composition of adjoint functors; units, counits and characterization of adjoint functors; equivalence gives adjoint functors.; Categorical properties: initial and terminal objects, products, coproducts; diagrams and (co)cones; (co)limits of a given shape; (co)equalizers, regularmono(epi) morphisms; pullbacks and pushouts; direct and inverse limits.; Constructing all (co)limits from some of them; (co)complete categories; absolute (co)limits; preservation, creation and reflection of (co)limits; right adjoints preserve limits. General adjoint-functor theorem; well-powered categories; special adjointfunctor theorem; examples. Definition of monads; monads arising from adjunctions; algebras for amonad; Eilenberg-Moore category; Kleisli category; Kleisli is initial while Eilenberg-Moore is terminal. Monadic functors; Beck's monadicity theorem; Crude monadicity theorem; examples. Special categories and applications: toposes, additive and

			abelian categories, symmetric monoidal categories, model categories.
MTH667	INTRODUCTION TO ALGEBRAIC GEOMETRY AND ALGEBRAIC GROUPS	3-0-0-0-9	Background from commutative algebra: Local rings, localizations, primary decomposition, Integral extensions, integral closures. Algebraic geometry: Affine algebraic sets, Hilbert Nullstellansatz, Projective algebraic sets, projective Nullstellansatz, Affine varieties, structure sheaf, Prevarieties, varieties, morphisms, Affine and projective algebraic sets are varieties, dimension of varieties, products of varieties, images and fibers of morphisms, Tangent spaces, differential of a morphism, Smooth morphisms, smooth varieties, complete varieties. Algebraic Groups: Basic definitions and examples, Lie algebra of an algebraic group, Linear representations of algebraic groups, Affine algebraic groups are linear; connected projective algebraic groups are abelian varieties, rigidity of abelian varieties, quotients, Homogeneous spaces, Chevalley's theorem on algebraic groups (without proof).
MTH668	INTRODUCTION TO ANALYTIC NUMER THEORY	3-0-0-0-9	Arithmetical functions Distribution of prime numbers; some elementary estimates. Characters of finite abelian groups. Riemann Zeta function and Dirichlet *L*-functions. Dirichlet’s Theorem on primes in arithmetic progression. Prime Number Theorem. Modular forms (for $SL_2(Z)$) and their *L*-functions. (If time permits) Prime number theorem for arithmetic progressions, exponential sums.
MTH669	ERGODIC THEORY AND APPLICATIONS TO METRIC NUMBER THEORY	3-0-0-0-9	Broadly the following topics are covered in details with varieties of examples and applications to metric number theory: Measure preserving transformation and its examples, Recurrence properties, Topological dynamics, Conditional expectations, Main ergodic theorems, Subadditive ergodic theorem, Ergodicity and its examples, Spectral approach to ergodicity, various applications of Birkhoff’s individual ergodic theorem, Mixing and its examples, Equidistribution, Unique ergodicity, Weyl’s theorem on equidistribution of polynomials, Ergodic measures are precisely the extreme points, Existence and uniqueness of conditional probability measures, Ergodic decomposition. If time permits, we may discuss several connections between Diophantine approximation and diagonal flows on the space of lattices and some recent developments.
MTH670	POTENTIAL THEORY IN THE COMPLEX PLANE	3-0-0-0-9	Harmonic functions and their basic properties; The Dirichlet problem on the unit disc; Positive Harmonic Functions, Harnack’s inequality and Harnack distance; Subharmonic functions; Maximum principle, Phragmen-Lindelof principle,

			Liouville's Theorem; Criterion for subharmonicity and Integrability; Convexity property of subharmonic functions and smoothing; Potentials and energy corresponding to it; Existence of equilibrium measure; Upper semicontinuous regularization, the Brelot-Cartan theorem; Minus infinity sets and removable singularities, the Rado-Stout theorem; Generalized Laplacians; Solution of the Dirichlet problem; Criterion for regularity; Harmonic measure; Green's functions and its properties and Riemann mapping theorem; The Poisson Jensen formula for subharmonic functions and its applications; Introduction to Capacity and computing capacity
MTH671	INTRODUCTION TO ARITHMETIC GEOMETRY	3-0-0-0-9	padic numbers: nonarchimedean absolute values, valuations, Ostrowski theorem, Cauchy sequences, padic integers, completions, Hensels lemma, structure of Z and Q. Quadratic forms: definition of quadratic forms and bilinear forms, equivalence of quadratic forms, local global principle (HasseMinkowski theorem), rational points on conics. [8 lectures]Infinite Galois Theory : Profinite groups and profinite topology, Infinite Ga lois extensions and Galois group as profinite groups, absolute Galois groups, the fundamental theorem of Galois theory (for infinite extensions), absolute Galois group of finite fields, Frobenius automorphism, absolute Galois group of Q and Qp.Geometry of curves over Q: Affine Varieties and projective varieties, curvesand function fields, divisors on curves, the RiemannRoch theorem (state ment without proof), Elliptic curves over Q, Group law on elliptic curves, Weierstrass equations, action of the absolute Galois group of Q over Q points of elliptic curves, Weak MordellWeil Theorem, MordellWeil Theorem, Faltings Theorem
MTH672	HARMONIC ANALYSIS ON POINCARE DISC	3-0-0-0-9	Pre-requisite(s): MTH 301, MTH 404/ Instructor's Consent Harmonic analysis on $\mathbb{R}$: Fourier Transform, basic properties, inversion formula, Plancherel formula, Paley-Wiener theorem, Young's inequality. Tangent space of $\mathbb{D}$, inner product on the tangent spaces of $\mathbb{D}$, $\frac{SU(1,1)}{SO(2)}$ as a Riemannian symmetric space, geodesics on $\mathbb{D}$, horocycles. Iwasawa decomposition, Cartan decompostion of $= SU(1,1)$, Haar measures in these decompositions, unimodular group. Laplace-Beltrami operator on $\mathbb{D}$ and its eigenfunctions, the Helgason-Fourier transform, Radon transform, elementary spherical functions, spherical transform, Abel transform, assymptotics of elementary spherical functions. Inversion and Plancherel formula for Helgason-Fourier transform, Paley-Wiener theorem, Helgason-Johnson's theorem, Kunze-Stein phenomena.

MTH673	ROBUST STATISTICAL METHODS	3-0-0-0-9	Pre-requisite: MSO201 / Instructor's consent Brief review of simple and multiple linear regression along with the outlier detection methods. Basic idea of non-parametric regression. Measures of robustness in different statistical problems (e.g., the influence function and the breakdown point). Least squares and least absolute deviations in regression model; Least median squares and least trimmed squares estimators; Different statistical properties and the computational algorithms of the robust estimators of the location and the scale parameters (for the univariate as well as the multivariate data); Robust measure of association and robust testing of hypothesis problems. Data-depth and the robust estimators based on the data-depth; Multivariate quantiles and its properties along with the computational algorithm; Possible extension of the depth-based and the quantile-based estimators for the functional data. Some applications of robust estimators (e.g., robust classification and cluster analysis), Robust model selection problems.
MTH674	VARIATIONAL METHODS IN PDE	3-0-0-0-9	Existence of Minimizer, Perron's Method variational form, Concentration-Compactness, Ekeland's Variational Principle, Palais-Smale Condition and Mountain Pass theorem, Application to semilinear equation with symmetry, Krasnoselskii Genus, Ljusternik-Schinelman Category, Multiple critical points of even functional on symmetric manifolds, Pohozaev Non-Existence Result, Brezis-Nirenberg result, Nehari Manifold and Fibering Method, Alexandrov's Moving Plane and Berestycki Sliding Method.
MTH675	GEOMETRY OF DIFFERENTIAL FORMS	3-0-0-0-9	Pre-requisite(s): MTH 201, MTH 304, MTH 305/ Instructor's consent Definition of manifolds and the fundamental ideas connected with them: Local coordinates, topological manifolds, differentiable manifolds, tangent spaces, vector fields, integral curves of vector fields and one-parameter group of local transformations, define manifold with boundary and orientation of a manifold. Differential forms on differentiable manifolds: Differential forms on Euclidean n-spaces and on a general manifold, the exterior algebra, Interior product and Lie derivative, The Cartan formula and properties of Lie derivatives. Frobenius theorem. The de Rham Theorem: Homology of manifolds, Integral of differential forms and the Stokes theorem. de Rham cohomology, The de Rham theorem. Applications of the de Rham theorem; Hopf invariant, the Massey product, cohomology of compact Lie

			groups, Mapping degree, Integral expression of the linking number by Gauss. Differential forms on Riemannian manifolds: The *- operator of Hodge, Laplacian and harmonic forms. The Hodge theorem and the Hodge decomposition of differential forms. Applications of the Hodge theorem.
MTH676	ECONOMETRICS	3-0-0-0-9	Brief review of topics in Multiple Linear Regression Analysis; Econometric tests on Heteroscedasticity and Autocorrelation; Restricted Regression; Errors in Variables; Functional Form and Structural Change; Stochastic Regressors; Instrumental Variable (IV) Estimation; Large Sample Properties of Least Square and IV estimators; Panel Data Models; Systems of Regression Equations -Seemingly Unrelated Regression Equations (SURE) & Multivariate Multiple Linear Regression; Simultaneous Equation Models - Structural and Reduced forms, Rank and Order conditions for Identifiability, Indirect Least Squares, 2-stage Least Squares and Limited Information Maximum Likelihood methods of estimation, k-class estimators and Full Information Maximum Likelihood Estimation; Models with lagged variables - Autoregressive Distributed Lag (ARDL) Models and Vector Autoregressive (VAR) Models; Topics on Econometric Time Series Models - Autoregressive and Generalized Autoregressive Conditionally Heteroscedastic (ARCH & GARCH) Models, Unit Root, Co-integration and Granger Causality.
MTH678	TECHNIQUES IN COMBINATORICS	3-0-0-0-9	Techniques in Combinatorics Pre-requisites: students are expected to have a very good background in Analysis-I (MTH301A), Algebra-I (MTH201A), Linear Algebra (MTH204A), Probability and Statistics as well as in Set theory and Logic (MTH302A) or Set theory and Discrete Mathematics (MTH202A). Some knowledge of the basics of graph theory and Fourier analysis is desirable but not mandatory. Aims of the course: Combinatorics is an area of mathematics that, at elementary level, deals with problems in counting/enumeration, especially in the realm of finite sets. However, the supply of problems as well as the methods to solve them come from a variety of domains of mathematics ranging from algebra, analysis, number theory, geometry, probability theory, and so on. Leon Mirsky has rightly said; combinatorics is a range of linked studies which have something in common and yet diverge widely in their objectives, their methods, and the degree of coherence they have attained. This, course will introduce techniques from three popular branches of combinatorics that are of areas of active research currently, namely extremal combinatorics, extremal graph theory and additive combinatorics over dyadic groups. The emphasis will be on the techniques than

			the solutions of the problems. Extremal combinatorics with set systems: Hall's marriage theorem, Sperner's lemma, Lubell-Yamamato-Meshalkin inequality, Kruskal-Katona theorem, Erdos Ko-Rado theorems [4 weeks]; 2. Extremal graph theory: Mantel & rsquo's theorem, Turan's theorem, Dirac's theorem, Erdos-Stone-Simonovits theorem, Szemeredi & rsquo's regularity lemma, Triangle,removal lemma, Roth's theorem for 3 term arithmetic progressions [4 weeks]; 3. Additive combinatorics with dyadic groups: Discrete Fourier transform, Plancherel & rsquo's theorem, Bogolyubov's lemma, Arithmetic regularity and removal lemmas, Coincidence of algebraic and statistical independence of Bernoulli r. v s, Rudin's inequality, Sets with small sumsets: Rusza's covering lemma, Freiman's theorem [5 weeks] **Course Reference**: 1. Bollobas. Combinatorics: set systems, hypergraphs, families of vectors, and combinatorial probability. Cambridge, University Press, 1986; 2. Extremal graph theory. Courier Corporation, 2004; 3. Tao, Terence, and Van H. Vu. Additive combinatorics Vol. 105. Cambridge University Press, 2006;
MTH679	SPATIO-TEMPORAL MODELS IN MATHEMATICAL BIOLOGY	3-0-0-0-9	Examples from nature and laboratory, Role of spatio-temporal models in biology. Linear Stability analysis: Formulation, Normal modes, Application to system of one, two and more variables. Bifurcation analysis: Introduction, Saddle-node, Pitchfork, Transcritical, Hopf and Hysteresis bifurcations. Spatial pattern formation: Reaction-diffusion system, Turing instability, Pattern formation in reaction-diffusion system. Chemotaxis: Introduction, Modelling chemotaxis, Linear and Nonlinear analysis. Tumor modelling: Introduction, Models of tumor growth, Moving boundary problems, Response of immune system. Numerical simulation of Spatio-temporal model: Introduction, Finite-difference techniques, Monotone methods.
MTH680	AN INTRODUCTION TO VON NEUMANN ALGEBRAS	3-0-0-0-9	Gelfand-Naimark theory, Commutative C*-algebras, Representations of C*-algebras, The spectral theorem, Polar decomposition, Compact operators, The three locally convex topologies, the GNS representation, Geometry of projections, Preduals and W*-algebras, Group von Neumann algebras, Group measure space construction, Crossed product algebras, vonNeumann's bicommutant theorem, Bounded Borel functional calculus, The Kaplansky density theorem, Normality and W*-algebras.
MTH681	STATISTICAL DECISION THEORY	3-0-0-0-9	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.
MTH682	ORDER STATISTICS	3-0-0-0-9	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.
MTH683	NON-PARAMETRIC INFERENCE	3-0-0-0-9	Order statistics, Tests of goodness of fit, Sign & signed rank tests, WaldWolfowitz, Kolmogorov Smirnov, Median & MannWhitney tests, Linear ranktests for the location problem & scale problem, Measures of association, Asymptotic relative efficiency.
MTH684	STATISTICAL SIMULATION, DATA ANALYSIS AND MODEL BUILDING	3-0-0-0-9	Introduction to simulation & MonteCarlo studies; Generation of random variables. Interactive computational & graphical techniques in model building; Data basedinference methods such as JackKnife, Bootstrap and cross validation techniques; Use of statistical packages in data analysis.
MTH685	TIME SERIES ANALYSIS: FORECASTING AND CONTROL	3-0-0-0-9	Linear stationary processes, Auto covariance & spectral density functions & moving average processes, Linear nonstationary processes, Model estimation & identification, Forecasting, Transfer function models, Design for discrete control.
MTH686	NON-LINEAR REGRESSION	3-0-0-0-9	Estimation methods, Commonly encountered problems in estimation, Statistical inference, Multiresponse nonlinear model, Asymptotic theory, Computational methods.
MTH688	TOPICS IN ARITHMATIC	3-0-0-0-9	review of finite fields, polynomial equations over finite fields; ChevalleyWarning theorem. Quadratic residue; law of quadratic reciprocity. p-adic numbers and p-adic inegers. Hensel's Lemma. Quadratic forms (over Q, Q_p and F_p). Riemann Zeta function and (Dirichlet) L-functions. Dirichlet's theorem on primes in arithmetic progression, prime number theorem. Modular forms (for $SL_2(Z)$); relation with elliptic curves.
MTH689	LINEAR AND NON-LINEAR MODELS	3-0-0-0-9	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.
MTH690	PROBABILISTIC THEORY OF PATTERN RECOGNITION	3-0-0-0-9	Results of convergence in almost sure sense and in probability, DCT, Basic inequalities, Conditional expectation, Methods of resampling. Introduction to discriminant analysis, Basyes; risk, and its properties. Distance measures for deensity functions, and its relation with Bayes; risk. Empirical Bayes; risk and its convergence. Parametric methods: Maximum likelihood principle Fisher's Linear Discriminant Function (LDA), Quadratic Discriminat Analysis (QDA). Consistency results. Logistic regression, Linear support vector machines (SVM), Maximum linear separation and Projection pursuit. Non-parametric methods: Kernel discriminant analysis (KDA), nearest neighbor classification (kNN), Universal consistencyh results. Idea of curse of dimensionality, and the use of dimension reduction techniques like random projections pricipal component analysis, etc. Semiparametric methods: Mixture Discriminant Analysis (MDA), Nonlinear SVM, Hybrid classifiesrs, Classification using data depth, Related consistency results. **Course Reference**: 1. Pattern Calssification by Richard

			Duda, Peter Hart and David Sstork, Wiley; 2. A Probabilistic Theory of Pattern Recognition by Luc Devroye, Laszlo Gyorfi and Gabor Lugosi. Springer; 3. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Trevor Hastie, Robert Tibshirani, Jerome Friedman. Springer. 05-apr-2016
MTH691	NUMERICAL LINEAR ALGEBRA	3-0-0-0-9	Triangular form, Matrix norms, Conditioning of linear systems, Direct methods (Gauss, Cholesky, Householder), Iterative methods (Jacobi, GaussSeidel, Relaxation) for solving linear systems, Computing of eigenvalues & eigenvectors (Jacobi, Givens Householder, QR, Inverse methods), Conjugate gradient method & its preconditioning.
MTH692	NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS	3-0-0-0-9	Introduction. RungeKutta methods derivation, error bounds and error estimates. Weak stability theory for RungeKutta methods. Order and convergence of the general explicit onestep methods. Linear multistep methods derivation, order consistency, zeros tability and convergence. Weak stability theory for genera llinear multistep methods. Predictor Corrector methods. Stiff systems.
MTH693	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3-0-0-0-9	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 twospace dimensions stability and convergence. Second order equations in one andtwo space dimensions. The Galerkin method and applications.
MTH694	COMPUTATIONAL FLUID DYNAMICS	3-0-0-0-9	Conservation laws, Weak solutions & shocks, Monotone difference schemes, Total variation diminishing schemes, Godunov type schemes, Essentially nonoscillatory methods, Flux limiters.
MTH695	EMPIRICAL PROCESSES	3-0-0-0-9	Preliminaries: Different Modes of Convergence, Law of Large Numbers, motivations. Function classes and their complexities, Glivenko-Cantelli class of functions. Symmetrization, Concentration Bounds. Vapnik-Cervonenkis (VC) classes of functions, Covering and Bracketing numbers, Examples: M-estimators. Donsker class, Uniform Central Limit Theorem, Examples. Arg-min continuous mapping theorem, Applications in Statistics: M-estimators,Lasso, Bootstrap consistency etc. More on Concentration Bounds/ Weak Convergence on Polish Spaces.
MTH696	SPECTRAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS	3-0-0-0-9	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.

MTH697	PROJECT-I	0-0-0-9-9	MS PROJECT-I
MTH698	PROJECT-II	0-0-0-9-9	MS PROJECT-II
MTH699	PROJECT-III	0-0-0-9-9	MS PROJECT-III
MTH700	PROJECT-IV	0-0-0-9-9	MS PROJECT-IV
MTH701	MODAL LOGIC	3-0-0-0-9	Modal Propositional Logic - Models and Frames, Consequence relations, Normal modal systems. Invariance results for models, Bisimulations, Finite model property, Translation into First order logic. Frame definability and Second order logic, Definable and undefinable properties. Completeness, Applications. Algebraic Semantics - Lindenbaum-Tarski Algebras, Jonsson-Tarski Theorem, Duality, Goldblatt-Thomason Theorem. Modal Predicate Logic - Axiomatization, Barcan formula, Soundness and Completeness, Expanding domains; Identity. Examples of some other modal systems and applications - Temporal logic with Since and Until, Multi-modal and Epistemic Logics. Non-normal modal logics. Neighbourhood semantics.
MTH702	ALGEBRAIC CURVES AND RIEMANN SURFACES	3-1-0-0-11	Algebraic curves in complex projective plane (Definition and Examples), Riemann surfaces (Definition and Examples); Holomorphic and meromorphic functions on Riemann surfaces (Definition and elementary properties); Holomorphic and meromorphic differentials, Residue Theorem and its consequences, Differential forms, Stokes' Theorem (without proof); Index of a differential form, divisors, The Poincaré-Hopf formula for real and meromorphic differentials, Statement of Riemann-Roch Theorem; Complex manifolds (Definition and Examples), holomorphic maps between complex manifolds, linear automorphisms of complex projective plane; Algebraic varieties, factorization of projective hypersurfaces, degree of a plane algebraic curve; Smooth points of an algebraic varieties, tangent spaces, C-R equations and a theorem of Osgood, Holomorphic implicit function theorem and local behaviour; Holomorphic mappings from compact Riemann surfaces into complex projective spaces, Rational canonical curve, Weierstrass P function, meromorphic functions on a compact manifold; Singularities of plane algebraic curves (Examples), The connectedness of irreducible plane algebraic curves, Riemann monodromy theorem (without proof); Normalization of irreducible plane algebraic curves (Definition), uniqueness theorem; Weierstrass polynomial, Weierstrass preparation theorem and its consequences; The

			local structure of plane algebraic curves, local normalization, normalization theorem, Bezout's theorem; Genus degree formula and Riemann-Roch Theorem
MTH702M	INTRODUCTION TO PROFESSION AND COMMUNICATION SKILLS (STATISTICS)	3-0-0-0-5	(1) In the first three weeks of the course two lectures, each of one and half hour duration, every week are given by faculty members on a fundamental topic in Statistics. (2) In the remaining weeks, students should present a topic in Statistics of their choice. Their talk should contain statistical concepts, and some proofs. Students can make their presentations individually or in pairs.
MTH703	FRACTIONAL SOBOLEV SPACES AND FRACTIONAL PARTIAL DIFFERENTIAL EQUATIONS	3-0-0-0-9	Some motivations from Probability theory for such spaces. Introduction of the Fractional Sobolev spaces. Definition via Fourier transform on R^n. Density results, Extension Theorem. Compact Embeddings Theorems. Holder Regularity Results. Fractional Poincarè Inequality, Fractional Sobolev and Hardy's Inequality. Fractional Laplace operator, Asymptotic behaviour of the constants and the operators as $s \to 0^+$ and $s \to 1^-$, Study of the Dirichlet problem for partial differential equations involving fractional Laplace operator.
MTH705	WAVELET METHODS FOR ELLIPTIC PARTIAL DEFFERENTIAL EQUATIONS	3-0-0-0-9	Few Elements of Sobolev Spaces and Variational formulations, Besov spaces, Multi-scale Approximation and Multi-resolution, Elliptic Boundary Value Problems, Multi-resolution Galerkin Methods, Wavelets, Wavelet Galerkin Method, Adaptive Wavelet Methods, Wavelets on General Domains, Some Applications.
MTH706	NUMERICAL ANALYSIS & SCIENTIFIC COMPUTING	3-0-0-0-9	Approximation of functions, Numerical quadrature, Methods of numerical linear algebra, Numerical solutions of nonlinear systems and optimization, Numerical solution of ordinary and partial differential equations.
MTH707	MARKOV CHAIN MONTE CARLO	3-0-0-0-9	This course presents the theoretical and practical challenges of implementing a discrete-time general state space Markov chain Monte Carlo algorithm. Metropolis-Hastings, Gibbs samplers, and other component-wise algorithms are discussed in detail. The theoretical part of the course focuses on studying rates of convergence of Markov chains, and establishing the existence of a Markov chain central limit theorem. The practical challenges of implementing these algorithms, such as step-sizes, stopping criterion, output analysis, and implementation in statistical software are also discussed in detail.
MTH712	A FIRST COURSE IN ALGEBRAIC NUMBER THEORY	3-0-0-0-9	A brief review of commutative algebra Localization, Noetherian rings and modules, integral extensions, Dedekind domains and discrete valuation ring, Spec of ring. Number field, ring of integer, primes and ramifications. Class group, initeness of class number, Dirichlet's unit theorem.

			Global fields, local fields, valuations. Cyclotomic fields. Zeta functions and Lfunctions, class number formula. Adeles and ideles. **Course Reference**: 1. Number Fields, D. Marcus, Universitext, SpringerVerlag; 2. Problems in Algebraic Number Theory, E. Jody and M.Ram Murty, GTM 190, Springer Verlog; 3. Algebraic Number Theory, J.S. Milne, Course notes, available at http://www.jmilne.org; 4. Algebraic Number Theory, J. Neukirch, Grundlehren der Mathematischen Wissen schaften 322, SpringerVerlog; 5. Algebraic Number Theory, S. Lang, GTM 110, SpringerVerlog; 6. A course in Arithmetic, J P Serre, GTM 7, SpringerVerlog; 7. Algebraic Number Theory, R. Narasimhan et.al, TIFR Pamphlet, available at www.math.tifr.res.in/ publ/pamphlets/index.html; 8. Introduction to commutative algebra, M.F. Atiyah, and I.G. Macdonald, AddisonWesley Publishing Co.
MTH713	DIFFERENTIAL TOPOLOGY	3-0-0-0-9	Several variables calculus: Review of inverse function theorem and implicit function theorem. Introduction to differential manifolds, sub-manifolds and manifolds with boundary. Smooth maps between differential manifolds, tangent space, differential of smooth maps, (local) diffeomorphism. Immersions, embeddings, regular value, level sets, submersions. Tangent and cotangent bundles, vector bundles, vector fields, integral curves. Transversality. Whitney embedding theorem. Sards theorem, Morse lemma, Morse functions. Oriented intersection Theory: degree, Lefchetz fixed point theory, the Poincaré-Hopf theorem. The Euler characteristic and triangulations. Integration on manifolds.
MTH715	FREDHOLM THEORY	3-0-0-0-9	Pre-requisite: MTH 405 / Instructor's Consent Compact Operators, Fredholm Alternative, Fredholm Operators, The Fredholm Index and the Abstract Index, Equality of Fredholm Index and Abstract Index, Essential Spectrum, Toeplitz Operators, Fredholm Theory for Toeplitz Operators, Connectedness of the Essential Spectrum
MTH716	INTRODUCTION TO GEOMETRIC ANALYSIS	3-0-0-0-9	Overview of Riemannian Geometry: Definition of Manifolds, Diffeomorphism, Sard's Theorem, Partition of Unity, Whitney embedding theorem, Tangent spaces and Tensor fields, Integration on Manifold, Stokes Theorem, Metric Tensor, Hodge Star Operation, Stokes theorem for Riemannian Manifold, Lie Derivative, Connection, Geodesic, Riemannian Curvature, Ricci tensor, Bianchi Identity. Sobolev Spaces in Riemannian Manifold: Definitions, Density, Imbedding Theorem, Trace Theory. Linear PDE in Riemannian Manifold: Existence theory

			of Poisson equation, Harmonic Forms, Hodge Decomposition, Spectral theory, Gromov's Isoperimetric Inequality, Green's Function of the Laplacian.
MTH717	ANN/ML APPROACH FOR DIFFERENTIAL EQUATIONS	2-0-1-0-9	Basics of ANN-(Introduction, Architecture of ANN, Learning Paradigms, Learning Rules/Processes, Activation Functions); Recall of ODEs/PDEs; Multilayer ANN Model(MANNM) for DEs –Structure of MANN, Formulation and Learning Algorithms For MANNM IVPs/BVPs/ODE-system/HODEs; Regression based ANN Model (RBANNM) for Des; Single layer functional link ANN Model (SLFLANNM) for Des; SLFLANNM with Regression Based weights; Application to Lane-Emden Equation, Emden Fowler Equation, Duffing Oscillator Equation, Van der Pol – Duffing Oscillator Equation; Simple introduction to Deep LearningApproach; Deep Galerkin Method and Implementation; Applications of DL to PDEs
MTH718	GAMMA CONVERGENCE	3-0-0-0-9	Introduction: Motivation of the Γ-convergence with 4 important examples. ΓCongervence by numbers: Lower and upper limits, Several definitions of Γconvergence, convergence of minima, upper and lower Γ-limits, properties of Γ-limits, Γ-limits indexed by a continuous parameter. Integral Problems: Relaxation and Gamma convergence in L^p spaces. Γ-convergence and convex functional. Phase Transition problem: Phase transition as segmentation problem, Gradient theory of phase transition problem, Gradient theory from point of view of Gamma convergence. Dimension Reduction problem: Problems on thin domains, Construction of recovery sequence, Non convex vector valued problem.
MTH719	INTRODUCTION TO HOMOGENIZATION	3-0-0-0-9	Pre-requisite: MTH 424/ Instructor's Consent Periodic composite materials (one dimensional and layered materials), Homogenization of second order el- liptic equations: periodic case, Tartar's method of oscillating test functions; Convergence of energy and correctors, Method of Two-scale convergence and convergence result, Homogenization in the non-periodic case (G-convergence and H-convergence), Optimal bounds: Hashin-Shtrikman.
MTH720	NUMERICAL SOLUTION OF INTEGRAL EQUATIONS	3-0-0-0-9	Introduction to integral equations, degenerate kernel method, projection methods, They Nystrom method, Solving multivariable integral equations, integral equations on a smooth and piecewise smooth planar boundary, boundary integral equation in 3 dimensions. **Course Reference:** 1. Kendall E. Atkinson: The numerical solution of integral equations of the second kind, Cambridge University Press; 2. Rainer Kress: Linear Integral Equations, Springer.
MTH721	COMPUTATIONAL	3-0-0-0-9	Introduction to Finite Difference Method (FDM), General

	FINANCIAL MATHEMATICS-A PDE APPROACH		Theory of FDM, FDM for 1-DEquations, Explicit FDM for One-Factor Models, Trinomial method for Barrier Options, Exponentially Fitted FDM for Barrier Options, Computational issues in Barrier and Look-back option models, FDM for One-Factor Black-Scholes Equation, Implicit-Explicit Method for Jump Process in Black Scholes Equations, FDM for Multi-Factor Instrument Pricing, Heston Model, Asian Option, Multi-Asset option, Front fixing Method, American Option.
MTH722	INTRODUCTION TO HOMOTOPY THEORY	3-0-0-0-9	Week 1 CW complexes, higher homotopy groups Week 2 Relative homotopy groups,properties, action of fundamental group. Week 3 Long exact sequence of a pair, Whitehead Theorem. Week 4 Cellular and CW approximation. Week 5 Postnikov Towers, k-invariants, Whitehead towers. Week 6 Freudenthal Suspension Theorem, Homotopy Excision Theorem and computations. Week 7 Moore spaces and Eilenberg–MacLane space. Week 8 Hurewicz Theorem. Week 9 Homotopy Lifting Property, Fibrations, fiber bundles. Week 10 Long Exact Sequences for fibrations, applications to spheres. Week 11 Whitehead products, stable homotopy groups, ring structures. Week 12 Loop spaces & Suspension, exact and co-exact Puppe sequences. Week 13 Relations to cohomology theory. Week 14 Obstruction Theory.
MTH723	PDE BASED IMAGE PROCESSING	3-0-0-0-9	Introduction to Image Processing; Mathematical Preliminaries–Direct Method in Calculus of Variation, Space of functions of Bounded Variations, Viscosity solutions of PDEs, Elements of Differential Geometry; Image Restoration-The Energy Method, PDE-Based Methods Smoothing & Enhancing PDEs Linear & Nonlinear Diffusion models, Classical & Curvature based morphological process; The Segmentation Problem, The Mumford and Shah Functional, Geodesic Active Contours, Level set Method; Applications from computer vision– Sequence Analysis, Image Classification etc.
MTH724	AN INTRODUCTION TO ALGEBRAIC K-THEORY	3-0-0-0-9	Projective modules, vector bundles, symmetric monoidal categories, exact categories. The Grothendieck group and K_0 of rings. Topological K-theory and Swan's theorem. Bass' K_1 and K_2 for rings. Geometric realization of a category. Quillen's $S^{-1}S$ construction and + construction.
MTH725	HILBERT SPACE METHODS IN COMPLEX ANALYSIS	3-0-0-0-9	Pre-requisite: MTH403 and MTH 405 / Instructor's Consent Functional Calculi, The Spectral Theorem; Hardy Space, the Unilateral Shift, Beurling's Theorem; Von Neumanns Theory of Spectral Sets; The Schur Class and Spectral Domains; The Sz.-Nagy Dilation Theorem and Ando's Dilation Theorem; The Sarason Interpolation Theorem; A Model Formula for Schur class, Lurking Isometries; The Muntz-

			Szász Interpolation Theorem, Pick Interpolation; The Corona Problem, Carleson's corona theorem, Leechs theorem/Toeplitz corona theorem; Operator Monotone Functions, Löwner's Theorems, Locally Matrix Monotone Functions in d Variables; The Löwner Class in d Variables, Globally Monotone Rational Functions in Two Variables
MTH726	COMBINATORIAL SET THEORY	3-0-0-0-9	Review of cardinal arithmetic, Cardinal exponentiation, Cofinality, Non-stationary ideal and club filter, Diagonal intersection and Fodor's lemma, Banach measure problem, Ulam's dichotomy and real valued measurable cardinals, Suslin's problem, Diamond principle and construction of Suslin line, Martin's axiom and its applications to measure and category on the real line, Walks on ordinals and their characteristics, Partition relations, Some open problems.
MTH727	SET THEORY AND FORCING	3-0-0-0-9	Review of ZFC and cardinal arithmetic, Infinite combinatorics, Inner models, Absoluteness and the reflection principle, Godel's constructible universe as a model of AC and GCH, Forcing posets and generic extensions, Definability of truth in generic extensions, Cohen forcing and the consistency of the negation of CH, Countably closed forcing and the consistency of the diamond principle, Martin's axiom, Suslin's hypothesis and almost disjoint forcing, Applications of forcing.
MTH728	REDUCED BASIS METHODS FOR PDES	3-0-0-0-9	Pre-requisites: MTH 308, MTH430 Introduction; Mathematical Preliminaries; Parametrized Differential Equations; Reduced Basis Methods; Certified Error Control; Emperical Interpolation Method; Linear Problems; Time Dependent Problems; Nonlinear Problems; Non-Coercive Problems with Examples
MTH729	ERGODIC THEORY	3-0-0-0-9	Measure Preserving Transformations, examples, flows, conditional probability and basic of topological groups. Ergodic Theorems, Ergodicity and Mixing. Almost everywhere convergence. Entropy, Selected topic from the following: Recurrence and Szemeredis Theorm/ Topological Dynamics/ Ornstein Theory/ Finitary coding between Bernoulli shifts and entropy invariance. **Course Reference:** 1. P. Walters: Introduction to Ergodic Theory; 2. K. E. Petersen: Ergodic Theory; 3. Ya. Sinai: Introduction to Ergodic Theory.
MTH731	INTRODUCTION TO COXETER GROUPS	3-0-0-0-9	The Coxeter groups find applications in many areas of mathematics. Understanding these groups involves the interplay of geometry, algebra, and combinatorics. The aim of this course is to familiarize students with the general theory of Coxeter groups and their Hecke algebras. Emphasis will also be on studying the examples of finite and affine reflection groups. This course will cover many topics such as Reflection groups and their generalizations, Coxeter systems, permutation representations, reduced words, Bruhat order, Kazhdan-Lusztig theory, Chevalley's theorem, Poincaré series, root systems, classification of finite and

			affine Coxeter groups.
MTH732	REPRESENTATION THEORY OF FINITE GROUPS	3-0-0-0-9	Basic representation theory, Irreducible representations and Maschke's theorem, 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, Regular representation and decomposition, Number of irreducible representations of a group. Induced representation. Character table of some known groups. Representation theory of symmetric and alternating group for small values of n. Algebraic integers and Burnside's pq theorem. Frobenius reciprocity formula, Group algebra and its decomposition, Mackey's irreducibility criterion. Artin's theorem on Induced characters, Elementary subgroups and Brauer's theorem.
MTH733	REPRESENTATION THEORY OF LINEAR LIE GROUPS	3-0-0-0-9	Linear groups: Topological groups; Linear groups (e.g., , and their topological properties (e.g., compactness, connectedness) Exponential: Exponential of a matrix, Logarithm of a matrix. Linear Lie groups: One parameter subgroups; Lie algebra of a linear Lie group; Linear Lie groups are submanifolds; Campbell-Hausdorff formula. Lie algebra: Definitions and examples; Semisimple Lie algebras; Nilpotent and solvable Lie algebras. Representations of compact groups: Unitary representations; Schur orthogonality relations; Peter-Weyl theorem; character and central functions; absolute convergence of Fourier series; Casimir operator. Haar measure: Definition; differential forms and Haar measure on linear Liegroup; Unimodular group and examples. Analysis on SU(2): Haar measure on SU(2); irreducible representations of SU(2);Laplace operator on SU(2); Fourier series on SU(2); Heat equation on SU(2). Analysis on U(n): Highest weight theorem; Weyl integration formula; Character formula; Dimension formula; Laplace operator, Fourier series and Heat equation on U(n).
MTH734	BANACH ALGEBRAS, C* ALGEBRAS AND SPECTRAL THEORY	3-0-0-0-9	Basics of Banach Algebras and C^*-algebras, examples, spectrum. Commutative Banach Algebra and C^*-algebras; maximal ideal spaces, Gelfand Transform; normal elements, continuous functional calculus. Representations of C^*-algebras, von Neumann Algebras, WOT and SOT, density theorems, double commutant theorem. Spectral Theorem for normal operators. Abelian von Neumann algebras (**Time permits**: Type-I von Neumann algebras, factors, constructions of Type-II factors).
MTH736	FOURIER ANALYSIS & DISTRIBUTION THEORY	3-0-0-0-9	Introduction, Test function spaces, Calculus with distributions, supports of distributions, Structure theorems, convolutions, Fourier transforms, L1, L2 theory of Fourier Transform, Tempered distributions, Paley Wiener theorem, wiener Tauberian theorem, Applications of distributions theory and Fourier transform to differential equations.
MTH739	TOPICS IN LIE GROUPS AND LIE ALGEBRAS	3-0-0-0-9	Definition of Lie group, Lie algebra and examples. Tangent Lie algebras Lie algebras associated to Lie groups. Correspondence between Lie algebras and simply connected Lie groups. The universal enveloping algebra of a

			Lie algebra and its properties. Hopf algebras and some basic Examples. Poincare-Birkhof -Witt theorem and deformations. Formal deformation of associative algebras. Formal deformation of Lie algebras. Cohomology of Lie algebras and its relation to deformation. Solvable, Nilpotent and semi-simple Lie algebras. Engel's theorem and Lie's theorem. The radical of a Lie algebra. Cartan criterion, Whitehead and Weyl theorems.
MTH751	ALGEBRA	3-0-0-0-9	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, Eigen values and Eigen vectors, Caley Hamilton theorem, Characteristic and minimal polynomial, diagonalization, Vector spaces, Linear transformations, Inner product spaces.
MTH752	MATHEMATICAL METHODS	3-0-0-0-9	Calculus of Variations; Sturm Liouville Problem and Green’s Function; Perturbation Methods and Similarity Analysis; Stability Theory.
MTH753	ANALYSIS	3-0-0-0-9	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, Lpspaces.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 L2 as a Hilbert space.
MTH754	PROBABILITY THEORY	3-0-0-0-9	Algebras and sigma algebras; Measurable spaces; Methods of introducingprobability 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; ZeroorOne laws; Convergence ofseries; Strong law of large numbers; Law of iterated logarithm; Matringales and their basic properties.
MTH755	STATISTICAL INFERENCE	3-0-0-0-9	Population and samples; Parametric and nonparametric models; 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 forone and two sided hypotheses; Unbiased and similarity; UMPU tests in exponential families; Invariance and UMPI tests; LR tests; Asymptotic tests based on likelihoods; Chisquare 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.
MTH759	ALGEBRIC TOPOLOGY II	3-0-0-0-9	Definition of singular cohomology, axiomatic properties. Cup and cap product. Cross product and statements of Kunneth theorem and Universal coefficients theorem. Cohomology rings of projective spaces. Orientation of manifolds and Poincare duality. Definition of higher homotopy groups, homotopy exact sequence of a pair. Definition of bration, examples of brations, homotopy exact sequence of a bration, its application to computation of homotopy groups. Hurewicz homomorphism, The Hurewicz theorem. The Whitehead Theorem. Adjointness of loop and suspension, Eilenberg -Mac Lane spaces and cohomology (from Bredon).
MTH761	VECTOR BUNDLES AND CHARACTERISTIC CLASSES	3-0-0-0-9	Smooth Manifolds, Vector bundles, Constructing New vector bundles Out of Old. Grassmann Manifolds and Universal bundles, The classification of vector bundles.Characteristic-classes for vector bundles, Stiefel Whitney classes of manifolds, Characteristic numbers of manifolds, Thom spaces and the Thom isomorphism theorem, The construction of Stiefel Whitney classes, Chern, Pontryagin, and Euler classes. **Course Reference**: 1.J. P. May. A concise course in Algebraic Topology. Chicago Lectures in Mathematics. University of Chicago Press, Chicago, IL, 1999, pp.; 2.John W. Milnor and James D. Stasheff. Characteristic classes. Annals of Mathematics Studies, No. 76. Princeton University Press, Princeton, N. J.; University of Tokyo Press, Tokyo, 1974.
MTH770	NUMERICAL TECHNIQUES FOR NONLINEAR DYNAMICAL SYSTEMS	3-0-0-0-9	Newton's Method for Nonlinear Equations, Numerical Integration of ODEs, Numerical Calculation of Eigenvalues, Numerical Solution of ODE Boundary-Value problems. Discrete Time Model: Numerical Detection of Fixed Points, Periodic Orbits, Bifurcation diagrams. Continuous Time Model: Continuation of Equilibrium Curves, Numerical Detection of Bifurcation Points of Co-Dimension One and 3-0-0-0-9Two, Local and Global Bifurcation Diagrams. Spatio-Temporal Model: Numerical Solution of Reaction-Diffusion Equations, Travelling Waves, Turing Patterns, Coupled Map Lattice Model. Delay Differential Equations: Numerical Solution of Delayed Temporal Model and Spatio-Temporal Model.
MTH781	STATISTICAL	3-0-0-0-9	Introduction to pattern recongnition supervised and

	PATTERN RECONGNITION		unsupervised classification. Dimension reduction techniques: 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 analysisi. Linear and nonlinear support vector machines. Cluster analysis: hierarchical and nonhirerarchical techniques classification using Gaussian mixtures. Data depth: different notions of depth, concept of multivariate median, application of depth in supervised and unsupervised classification.
MTH784	STATISTICAL RELIABILITY THEORY	3-0-0-0-9	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 distri butions, 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 multi variate and dependence; Maintenance and replacement policies, Availability of repairable systems, Optimization of system reliability with redundancy.
MTH785	ECONOMETRIC THEORY	3-0-0-0-9	Multiple linear model, estimation of parameters under spherical and nonsphericaldisturbances by least squares and maximum likelihood methods, testsof hypothesis, R2 and adjusted R2. 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,inclusion 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. Hetero skedasticity, problem and test, estimation under Hetero skedasticity. Autocorrelation, DurbinWatson test. Errors invariables, 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.Simultaneousequations model, structural and reduced forms, rank and orderconditions for identifiability, indirect least squares, two stage least squares and imited information maximum likelihood methods of estimation. Additional topics like as Panel data models and unit roots & cointegration.
MTH799	PHD RESEARCH	0-0-0-9-9	Ph. D. Research
	PG SEMINAR COURSE MATHEMATICS I		PG Seminar course I for Ph.D (Mathematics) students
	PG SEMINAR COURSE		PG Seminar course II for Ph.D (Mathematics) students

	MATHEMATICS II		
	PG SEMINAR COURSE STATISTICS I		PG Seminar course I for Ph.D (Statistics) students
	PG SEMINAR COURSE STATISTICS II		PG Seminar course II for Ph.D (Statistics) students