ETERNAL UNIVERSITY
BARU SAHIB

SYLLABUS

Ph.D. Mathematics

(THREE YEARS FULL TIME PROGRAMME)

(SIX SEMESTER COURSE)

Approved by the Academic council in its 64th meeting held on August 06, 2019

DEPARTMENT OF MATHEMATICS
AKAL COLLEGE OF BASIC SCIENCES

Semester I			
Category	Course code	Course name	Credit
Compulsory course	MATH609	Research Methodology	3
Compulsory course	MATH607	Seminar	1
Elective course I			4
Elective course II			4
	MATH701	Research progress*	5

*Evaluation of progress related to His/her performance of activities related to research during the semester.

Elective Courses			
Sl. No.	Course code	Course name	Credit
1	MATH622	Stochastic Processes and its Applications	4
2	MATH623	Fuzzy Set theory	4
3	MATH624	Operations Research: Theory and its Applications	4
4	MATH625	Optimization Techniques	4
5	MATH626	Genetic Algorithm Artificial Neural Networks and Applications	4
6	MATH627	Application of Finite Element Method in Mathematical Modeling	4
7	MATH628	Digital Image Processing	4
8	MATH629	Graph Theory and its Applications	4
9	MATH630	Foundation of Wavelet and wavelet Analysis	4
10	MATH631	Advanced Time Frequency/Wavelet Transform Methods and their Applications	4
11	MATH632	Advanced Fluid Mechanics	4
12	MATH633	Dynamical Systems	4
13	MATH634	Topology and Differential Geometry	4
14	MATH635	Commutative Algebra	4
15	MATH636	Applied Functional Analysis	4
16	MATH637	Analysis	4

Semester II		
1	MATH638	Numerical Techniques and its Application in Differential Equations
2	Synopsis writing	
3	Approval of Synopsis by Research Committee (Synopsis Seminar)	

II, III, IV, and V & VI SEMESTER: The student will undertake his/her research work (MATH701) by taking 15 credit hours each semester. The major advisor will evaluate his/her work in each semester and clear the credit hours by evaluating satisfactory/unsatisfactory credits depending upon the work undertaken by the student during the semester.

Examination Schedule: As applicable to other postgraduate courses of Eternal University.

Course Code	Course Title	**Lecture**	**Tutorial**	**Practical**	Credit Hours
		3	**1**	**0**	
MATH-609	**Research Methodology**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	History, myths and ethnic practices; need, importance and impact of research; types of research; research process.				3
II	Synopsis writing: Selecting research problem; formulation of research projects; survey of literature; research infrastructure; experimental designs; sampling designs; recording of observations; measurement and scaling techniques; GLPs.				6
III	Formulation and types of hypothesis; collection, maintenance, storage and analysis of data; measures of central tendencies and relationships and error analysis; tests of significance.				6
IV	Compilation and presentation of results, writing of manuscripts; research reports and thesis; organization of reference material using endnote; bibliography; plagiarism; IPR and patent application, entrepreneurship.				5
V	Financial support and various funding agencies; Multidisciplinary and multi-institutional research; writing research proposal for external funding.				4
VI	Computer and informatics; introduction; word processing, excel, power point presentation; graph and figure plotting; web browsing; information resources and various databases.				6
VII	Demonstration of departmental research activities and instrumentation				14
	Recommended Books				Year
1	Kothari CR. Research methodology: Methods and techniques. New Age International.				2004
2	Kumar R. Research methodology: A step-by-step guide for beginners. Sage Publications Limited.				2019
3	Laake P, Benestad HB, Olsen BR, editors. Research methodology in the medical and biological sciences. Academic Press.				2007
4	Murthy C. Research Methodology, Vrinda Publication Pvt. Ltd. New Delhi.				2009
5	Gurumani N. Research Methodology: For Biological Sciences. MJP Publisher.				2019

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-609	**Research Methodology**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	History, myths and ethnic practices; need, importance and impact of research; types of research; research process.				3
II	Synopsis writing: Selecting research problem; formulation of research projects; survey of literature; research infrastructure; experimental designs; sampling designs; recording of observations; measurement and scaling techniques; GLPs.				6
III	Formulation and types of hypothesis; collection, maintenance, storage and analysis of data; measures of central tendencies and relationships and error analysis; tests of significance.				6
IV	Compilation and presentation of results, writing of manuscripts; research reports and thesis; organization of reference material using endnote; bibliography; plagiarism; IPR and patent application, entrepreneurship.				5
V	Financial support and various funding agencies; Multidisciplinary and multi-institutional research; writing research proposal for external funding.				4
VI	Computer and informatics; introduction; word processing, excel, power point presentation; graph and figure plotting; web browsing; information resources and various databases.				6
VII	Demonstration of departmental research activities and instrumentation				14
	Recommended Books				Year
1	Kothari CR. Research methodology: Methods and techniques. New Age International.				2004
2	Kumar R. Research methodology: A step-by-step guide for beginners. Sage Publications Limited.				2019
3	Laake P, Benestad HB, Olsen BR, editors. Research methodology in the medical and biological sciences. Academic Press.				2007
4	Murthy C. Research Methodology, Vrinda Publication Pvt. Ltd. New Delhi.				2009
5	Gurumani N. Research Methodology: For Biological Sciences. MJP Publisher.				2019

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-622	**Stochastic Processes and its Applications**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Rudiments of probability theory, Algebra of events, Discrete & Continuous random variables; their probability distributions, Moments of probability distributions, m.g.f & characteristic functions.				12
II	Dependence & independence of random variables, Sums of independent random variables. WLLN. Central Limit Theorem & Normal distribution.				11
III	Integer valued random variables & Poisson process, Compound Poisson variables & Poisson processes, Markov chains, Chapman-Kolmogorov equations. Limit theorems.				11
IV	The Gambler's Ruin problem. Branching processes, The Symmetric Random Walk. Stationary point processes, Martingales, Azuma's inequality, Sub-martingales, The Martingale convergence Theorem.				11
	Recommended Books				Year
1.	Karlin, Samuel and Taylor, Howard M., A First Course in Stochastic Processes Second Edition, Academic Press.				1975
2.	Ross, S. Stochastic Processes, 2nd Edition, Wiley.				1996
3.	Lawler, G.F. Introduction to Stochastic Processes, Second Edition, Chapman and Hall, Probability Series.				2006
4.	Ross, Sheldon M. Introduction to Probability Models, 9thedition, Academic Press.				2007

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-623	**Fuzzy set theory**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Basic definitions of Fuzzy set, α-cuts and additional its properties involving the standard fuzzy set operators and the standard fuzzy set inclusion, support, level set core and height of a fuzzy set, normal and subnormal fuzzy sets, convex fuzzy sets, cut worthy property, standard operations of fuzzy set, standard complement and intersection, equilibrium points, standard union, fuzzy set inclusion, scalar cardinality of a fuzzy set, the degree of subset hood, Representation of fuzzy sets, three basic decomposition theorems of fuzzy sets. Zedah's extension principle, images and inverse images of fuzzy sets., Types of operations.				12
II	Fuzzy complements, equilibrium of a fuzzy complement, first and second characterization theorems of fuzzy complements, fuzzy intersections (t-norms), standard fuzzy intersection as the only idempotent t-norm, standard intersection, algebraic product, bounded difference and drastic intersection as examples of t-norms, Decreasing generator, the Pseudo-inverse of a decreasing generator, increasing generators and their Pseudo inverses, conversion of decreasing generators and increasing generators to each other, characterization theorem of t-norms(statement only). Fuzzy unions (t-conorms), standard union, algebraic sum, bounded sum and drastic union as examples of t-co-norms, characterization theorem of t-conorms (Statement only).				11
III	Fuzzy numbers, relation between fuzzy number and a convex fuzzy set, characterization of fuzzy numbers in terms of its membership functions as piecewise defined functions, fuzzy cardinality of a fuzzy set using fuzzy numbers, arithmetic operators on fuzzy numbers, extension of standard arithmetic operations on real numbers to fuzzy numbers. lattice of fuzzy numbers, (R, MIN, MAX) as a distributive lattice, fuzzy equations, equation A+X = B, equation A.X = B.				11
IV	Crisp and fuzzy relations, projections and cylindrical extensions, binary fuzzy relations, domain, range and height of a fuzzy relation, membership matrices, sagittal diagram, inverse of a fuzzy relation, composition of fuzzy relations, standard composition, max-min composition, relational join, binary relations on a single set, directed graphs, reflexive irreflexive, anti-reflexive, symmetric, asymmetric, anti-symmetric, transitive (max-min transtitive), non-transitive, anti-transitive fuzzy relations., Fuzzy equivalence relations, fuzzy compatibility relations, α -compatibility class, maximal α-compatibles, complete α -cover, reflexive undirected graphs, fuzzy ordering relations, fuzzy upper bound, fuzzy pre ordering, fuzzy weak ordering, fuzzy strict ordering, fuzzy morphisms.				11
	Recommended Books				Year
1.	G.J. Klir and B. Yuan, Fuzzy Sets and Fuzzy Logic; Theory and Applications, Sixth Indian Reprint Prentice Hall of India, New Delhi.				2002
2.	Zimmermann, H.J., Fuzzy set theory and its applications, Kluwer Academic Publishers				2001

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-624	**Operations Research: Theory and its Applications**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Hyperplane and hyperspheres, Convex sets and their properties, convex functions, concave functions. Linear Programming Problem (LPP): Formulation and examples, Feasible, Basic feasible and optimal solutions, Extreme points. Graphical Methods to solve L.P.P., Simplex Method, Charnes Big M Method, Two phase Method, Degeneracy, Unrestricted variables, unbounded solutions. Infeasibility in L.P.P and their identification through Charnes M and Two-phase method. Their application in solving system of equations, finding rank of a matrix, finding inverse of a given non-singular matrix.,				12
II	Duality theory, Dual LPP, fundamental properties of Dual problems, Weak duality, strong duality, fundamental theorem of Duality, Weak Complementary slackness theorem, Strong complementary slackness theorem, Economic interpretation of Dual variables, Farka's theorem using duality, solutions of linear inequalities using duality theory, Dual simplex algorithm, Sensitivity analysis., Gomory's Method, Branch and Bound Method for pure and mixed integer programming problems,0-1programming problems and their solutions using branch and bound method.				13
III	Mathematical formulation Basic feasible solutions of Transportation Problems by North – West corner method, Least Cost-Method, Vogel's approximation method. Unbalanced TP, optimality test of Basic Feasible Solution (BFS) by UV method, Stepping Stone method, degeneracy in TP. Properties of coefficient matrix of balanced TP., Mathematical formulation, Assignment Problems, Hungarian method, convergence of Hungarian method, Unbalanced AP., Formulation of Goal Programming, Graphical Goal attainment method, simplex method for GPP.				10
IV	Two-person, zero-sum games, The maximin – minimax principle, pure strategies, mixed strategies, Graphical solution of 2 x n and m x 2 games, Dominance property, General solution of m x n rectangular games, Linear programming formulation and solution for m x n rectangular games. Shortest path model, Dijkastra algorithm, Floyd's algorithm, Minimal Spanning tree, Maximal flow problem. Max flow min cut theorem.				10
	Recommended Books				Year
1.	Sharma, S.D., Operations Research, Kedar Nath Ram Nath & Co. 14th Edition.				2004
2.	Swarup Kanti, Gupta, P.K. and Manmohan, Operations Research, 12th Edition, Sultan Chand & Sons.				2004
3.	Panneerselvam R., Operations Research, Prentice Hall of India Pvt. Ltd.				2004
4.	Hadley,G., Linear Programming, Narosa Publishing House.				2002

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	4
MATH-625	**Optimization Techniques**				
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Convex hulls, Closure and interior of a set, Weierstrass's Theorem, Separation and support of sets, Separation theorems of convex sets. Convex cones and polarity, Polyhedral sets, Extreme points and extreme directions, Linear Programming and Simplex method.				12
II	Definitions and Basic properties, Sub gradients of Convex functions, Differentiable convex functions, Twice differentiable convex functions, and their properties, Minima and Maxima of Convex functions, Generalization of Convex functions and their properties.				11
III	Fritz John and Karush-Kuhn-Tucker optimality conditions Unconstrained problems, constrained problems: Problems having inequality constraints, Problems having inequality and equality constraints, First and second order necessary and sufficient optimality conditions. Cone of Tangents, Other constraint qualifications, Problems having inequality and equality constraints.				11
IV	Lagrangian dual problem, Duality theorems and Saddle point optimality conditions, Properties of the dual function, Formulating and solving the dual problem, Getting the primal solution, Linear quadratic programs.				11
	Recommended Books				Year
1	Mokhtar S. Bazaraa, Hanif D. Sherali, C.M.Shetty Non Linear Programming: Theory and Algorithms, John Wiley & Son's, INC, Publication.				2004
2	S.M Sinha, Mathematical Programming Theory and Methods, 1st edition. Elsevier.				2002
3	Kambo N.S, Mathematical Programming Techniques, Affiliated East-West Press Pvt.Ltd. New Delhi, Madras.				1984
4	Beightler, C, Phillips, D., and Wilde, D. Foundations of Optimization, Prentice Hall, En-glewood Clifls, New Jersey.				1979

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-626	**Genetic algorithms, Artificial Neural Networks and Applications**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Genetic Algorithm (GA): Introduction, Mathematical foundations, Computer implementation ofa genetic algorithm, some application of GA, Advanced operators and techniques in genetic search, Genetic based machine learning.				14
II	Application of genetic based machine learning, Artificial Neural Network (ANN): Basics of Neuroscience and Artificial Neuron Model, Threshold gates.				12
III	Computational Capabilities of ANN, Learning Rules, Mathematical foundation of neural learning, Adaptive multilayer neural network, Associative neural memories, Global search method for neural networks.				10
IV	Applications of GA and ANN: TSP problem, Target tracking, Time series prediction, Speech generation and Speech recognition, Image processing and Computer Vision.				10
	Recommended Books				Year
1	David E. Goldberg, Genetic Algorithms in Search Optimization Machine Learning, ADDISON WESLE.				1989
2	Mohammad H. Hassoun, Fundamentals of Artificial Neural Networks, PHI,.				2010
3	CrisitaniniShawe-Taylor, An introduction to Support Vector Machines, Cambridge Press,.				2000
4	Applications, TATA McGRAW-HILL, 1996.T. M. Mitchell, Machine Learning, Mcgraw-Hill.				1997
5	N.K. Bose and P. Liang, Neural Network Fundamentals with Graphs, Algorithms and B. SchÖlkopf and A.J. Smola, Learning with Kernels, MIT Press,.				2002

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	0	1	
MATH-627	**Application of Finite Element Method in Mathematical Modeling**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Piecewise polynomial approximations in 1D: Piecewise polynomial spaces, Interpolation, L2 projection, Quadrature, computer implementation. Finite element method in 1D: The finite element method for a Model problem: A two-point boundary value problem, Variational Formulation, Finite Element approximation, Derivation of Linear System of Equations, Basic algorithm to compute Finite element solution.				14
II	Mathematical Modeling: Derivation of the Stationary Heat equation, Boundary condition for the Heat Equation, Derivation of differential equation for deformation of a Bar, A model problem with Variable coefficients and Robin Boundary conditions and Computer implementation.				12
III	Piecewise polynomial approximation in 2D, Meshes, Piecewise Polynomial spaces, Interpolation, L2 projection, Quadrature and Numerical Integration, and computer implementation, Finite element method in 2D: Green's formula, the Finite Element Method for Poisson's equation, Basic analysis of Finite Element Method, A problem with Variable coefficients and computer implementation. Dirichlet problem, Neumann problem, Eigen value problem, Adaptive Finite element Methods				10
IV	Time dependent problems: Heat equation, Stability estimates, A priori error estimate, Wave equation, Stability Estimate, A priori estimate and computer implementation				10
	Recommended Books				Year
1	The Finite Element Method: Theory, Implementation, and Applications, Larson, Mats G., Benzon, Fredrik, Springer-Verlag Berlin Heidelberg, Edition 1,				2013
2	Finite Element Method using Matlab, Y. W. Kwon and H. Bang, CRC press, 2nd				1994
3	Introductory Finite Element Method, C. S. Desai and T. Kundu, CRC press,				1982

Course Code	Course Title	**Lecture** **3**	**Tutorial** **1**	**Practical** **0**	Credit Hours
MATH-628	**Digital Image Processing**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Introduction, steps in image processing, Image acquisition, representation, sampling and quantization, relationship between pixels– color models – basics of color image processing.				14
II	Image enhancement in spatial domain, some basic gray level transformations, histogram processing, enhancement using arithmetic, logic operations, basics of spatial filtering and smoothing. Image enhancement in Frequency Domain-Introduction to Fourier transform: 1- D, 2-D DFT and its inverse transform, smoothing and sharpening filters.				12
III	Image restoration: Model of degradation and restoration process – noise models – restoration in the presence of noise- periodic noise reduction. Image segmentation: Thresholding and region-based segmentation.				10
IV	Image compression: Fundamentals – models – information theory – error free compression –Lossy compression: predictive and transform coding. JPEG standard				10
	Recommended Books				Year
1	R.C. Gonzalez, R.E.Woods, , Digital Image processing, 2nd Edition, Pearson Education.				2002
2	Anil K. Jain,Fundamentals of Digital image Processing, 2nd Edition, Prentice Hall of India, New Delhi.				1994
3	Pratt. W.K., Digital Image Processing, 3rd Edition, John Wiley & Sons.				1982
4	Rosenfled A. &Kak, A.C, Digital Picture Processing, vol .I & II, Academic Press.				2004

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-629	**Graph Theory and its Applications**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Fundamentals of graph theory, families of graphs, and digraphs, Computer representation of graphs, graph isomorphism, reconstruction problem, and recursively constructed graphs. Basic digraph models and properties, directed acyclic graphs, Tournaments, Connectivity properties and structure, Eulerian graphs, Chinese postman problems, De Bruijn graphs and sequences, Hamiltonian graphs, Traveling salesman problems. Graph coloring, independent sets and cliques, Factors and factorization, Perfect graphs, Applications to timetabling.				14
II	Algebraic graph theory – Auto-morphisms, Cayley graphs, enumeration, graphs and vector spaces, spectral graph theory, and matroidal methods in graph theory. Topological graph theory				12
III	Graphs on surfaces, minimum and maximum imbedding's, genus distribution, voltage graphs, genus of a group, maps, representativity, triangulations, graphs and finite geometries. Analytic Graph Theory - Extremal graph theory, random graphs, Ramsey graph theory, and probabilistic methods.				10
IV	Graphical measurement - Distance in graphs, domination in graphs, tolerance graphs and bandwidth, Applications in computer science - searching, dynamic graph algorithms, drawings of graph, and algorithms on recursively constructed graphs. Application in networks and flows - Maximum flows, minimum cost flows, matchings and assignments, and communication networks.				10
	Recommended Books				Year
1	Jonathan L Gross, Jay Yellen, Handbook of Graph Theor				2003
2	Richard A. Brualdi, Introductory Combinatorics, Prentice Hall, 4 editions				2004
3	G. Chartrand and L. Lesniak, Graphs and Digraphs, Chapman & Hall/CRC, 4 editions,				2004
4	Bondy J.A. and U.S. R. Murty, Graph Theory with Applications, The Macmillan Press Ltd.				2004
5	DeoNarsingh, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall, India,.				1994

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-630	**Foundations of Fourier and Wavelet Analysis**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Introduction to Metric and Normed Spaces: Metric Space, Normed Space, Inner Product Space, Orthogonality, L2, l2 and Lp spaces and their properties, concept of convergence, point wise and uniform convergence, different inequalities in L2, l2 and Lp spaces. The Bases - Best approximation, orthogonal complement and projection theorem, Orthonormal basis, orthogonal direct sums, Dual Spaces and Adjoints.				14
II	The Fourier Series: Historical perspective, Computation of Fourier series on interval $[-\pi, \pi]$, on general interval, Cosine and Sine Expansion. Complex form of Fourier series, Convergence of Fourier series, Riemann-Lebesgue Lemma, Convergence at a point of continuity, Convergence at a point of discontinuity, Uniform convergence, Convergence in the Mean.				12
III	The Fourier Transform (L1(R) L2(R),): Development of Fourier transform, Fourier inversion theorem, Properties of the Fourier Transform – Basic properties, Poisson summation formula, Fourier transform of a convolution, approximate identity, Adjoint of the Fourier transform. Linear filters, Sampling theorem, and Uncertainty Principle. Discrete Fourier transform; Definition, properties, and Fast Fourier Transform approximation to the Fourier Transform.				10
IV	Wavelet Analysis and Wavelet Transform: Why wavelets, Haar wavelet – Scaling function and its different properties. Haar decomposition and reconstruction algorithm, Daubechies wavelets - Daubechies construction; classification, Moments, and Smoothness; Computational issues; The scaling function at dyadic points. Wavelet Transform - Definition of Wavelet transform, Relation with Fourier Transform, Inversion formula for the Wavelet Transform, Local properties. Other Wavelet Topics: Idea of multiresolution analysis, Wavelets in higher dimensions, Wavelet packets, Orthogonality and Scaling equation via Fourier transform. Applications: Signal enhancement, function approximation, deconvolution, image processing, speech processing etc.				10
	Recommended Books				Year
1	Albert Boggess and Francis J.Narcowich, A First Course in Wavelets with Fourier Analysis, WILEY.				2009
2	George Bachman, Lawrence Narici, Edward Beckenstein, Fourier and Wavelet Analysis, SPRINGER.				2000
3	Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, 1992. 5. E.Hernandez, G. Weiss, A First Course on Wavelets, CRC Press.				1996
4	John G. Proakis, Dimitris G. Manolakis, Digital Signal Processing - Principles, Algorithms and Application, 3rd edition, Pearson Education.				2004
5	Stephen Mallat, A Wavelet tour of signal processing the sparse way, 3rd edition, Academic Press.				2009
6	R.S. Pathak: The Wavelet Transform, Atlantis Press/World Scientific.				2009

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-631	**Advanced Time-Frequency / Wavelet Transform Methods and Their Applications**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		

Unit	Contents	Lectures
I	Fourier analysis: A brief review; the uncertainty principle, Non-stationary signals, time-variant systems and the weakness of Fourier analysis.	14
II	Time-Frequency methods: An overview and classification, Continuous and discrete short-time Fourier decompositions and the Gabor representation (continuous time). Tiling options of the time-frequency domain. The continuous wavelet transform, Discrete wavelet transforms. Properties and outstanding features, Frame theory, Gabor and wavelet frames, the construction of orthonormal wavelet bases and Multiresolution Analysis. Orthonormal wavelet bases of finite support with Examples, Wavelet analysis of discrete-time signals and Malat's algorithm, Wavelets and perfectly-reconstructable filter-banks. Bi-orthogonal wavelet bases: Symmetry and linear-phase. Spline wavelets, Implementation: complexity and numerical efficiency, Adaptive decompositions: Information cost functions, library of bases.	12
III	Orthogonal and Bi-orthogonal Wavelet Packets: Additive cost functions and complexity, Adaptive decompositions based on local-trignometric libraries. Advantages and drawbacks compared to Wavelet Packets, The importance of shift-Invariance in various applications, Discrete, shift-invariant decompositions, Shift-Invariant Wavelet Packets libraries and decompositions and examples.	10
IV	Multi-dimensional (primarily two –dimensional) adaptive and non-adaptive decompositions, Observations and some results from Approximation Theory, the weakness of wavelet decompositions in representing (first order) line-discontinuities, Lin-discontinuities in Radon space, Donoho's Ridgelets and related concepts, Time-Frequency Distributions: Expectations and basic properties. The Winger Distribution: Its outstanding properties and drawbacks, Modified Winger Spaces. Application examples will be selected to fit student's interest. (Function Approximation, Interpolation, Image De noising, Deconvolution, Estimation, Computed Tomography, ECG and EEG signal analysis).	10

	Recommended Books	Year
1	Ingrid Daubechies, Ten Lectures on Wavelets, SIAM.	1995
2	C.S. Burns, R.A. Gopinath, and H. Guo, Introduction to Wavelet and Wavelet Transform, Prrintice Hall, New Jersey.	1998
3	M. Vetterli and J. Kovaceive, Wavelets and Subband Coding, Prentice-Hall, PTR, Englewood Cliffs, NJ.	1995
4	G. Strang and T. Nguyen, Wavelets and Filter Banks, Wellesley-Cambridge Press.	1996
5	Stephen Mallat, A Wavelet tour of signal processing the sparse way, Academic Press.	2009

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-632	Advanced Fluid Mechanics				4
Relative Weightage	IAE 50	ETE 50	PRE 0		
Unit	Contents				Lectures
I	Real fluids and ideal fluids, velocity of fluid at a point, streamlines, pathlines, streamlines, velocity potential, vorticity vector, local and particle rate of change, equation of continuity, irrotational and rotational motion, acceleration of fluid, conditions at rigid boundary, Euler's equation of motion, Bernoulli's equation, Potential theorems, axially symmetric flows.				14
II	Impulsive motion, Kelvin's Theorem of circulation, equation of vorticity, some three-dimensional flows, sources, sinks and doublets, images in rigid planes, images in solid sphere. Stoke's stream function, Complex velocity potential, Milne Thomson Circle Theorem, Theorem, of Blasius, Vortex rows.				12
III	Karman vortex street Stress components, Stress and strain terror, Coefficient of viscosity and Laminar flow, Plane Poiseuille flows and Couette flow, Flow through tubes of uniform cross section in the form of				10
	circle, Ellipse, equilateral triangle, annulus, under constant pressure gradient, Diffusion of Vorticity, Energy dissipation due to viscosity.				
IV	Steady flow past a fixed sphere, dimensional analysis, Reynold numbers, Prandtl's boundary layer. Boundary layer equation in two dimensions, Karman integral equation, Elements of wave motion; waves in fluids, Surface gravity waves, group velocity, energy of propagations, path of particles, waves at interface of two liquids.				10
	Recommended Books				Year
1	Text Book of Fluid Dynamics, Chorlton, F. 1st Edition CBS Publishers & Distributors, 2005.				2001
2	Fluid Mechanics, Fluid Dynamics, Landau, L. D. & Lipschitz, E. N. : Pergaman, New York.				2004.
3	An Introduction to Fluid Mechanics, Batchler, G. K. Cambridge University Press.				2000.
4	A Treatise on Hydromechanics, Besant, W. H. and Ramsey, A. S., G. Bell and Sons, Limited.				2000
5	A Text Book of Fluid Mechanics, Bansal, R.K, Laxmi Publications				2006

Course Code	Course Title	**Lecture**	**Tutorial**	**Practical**	Credit Hours
		3	**1**	**0**	
MATH-633	**Dynamical Systems**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Linear and Nonlinear Dynamical Systems, Applications of Dynamical Systems in Biology, Circuit Theory, Mechanics, Cosmology and Astrophysics.				14
II	Limit Sets and Attractors, Periodic Orbits, Stable Manifold Theorem for Periodic Orbits, Persistence and Uniform Persistence of Dynamical Systems.				12
III	Hyperbolic and Non-hyperbolic Critical Points, Structural Stability, Bifurcation Theory: Saddle Node Bifurcations, Trans critical Bifurcations, Pitchfork Bifurcations, Hopf Bifurcation, Homoclinic Bifurcations.				10
IV	Dynamical Systems with MATLAB.				10
	Recommended Books				Year
1	Lawrence Perko, Differential Equations and Dynamical Systems, Springer-Verlag, New York, Inc.				2001
2	M. W. Hirsch, S. Smale, R. L. Devaney, Differential Equations, Dynamical Systems & An Introduction to Chaos, Elsevier Academic Press USA,.				2004.
3	S. Lynch, Dynamical Systems with Applications using MATLAB, Birkhauser Boston.				2004.

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-634	**Topology and Differential Geometry**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Topology: Topological spaces, Connected and Compact spaces, Homeomorphism. Differential Manifolds: Definition and examples, Calculus of Manifolds and differential forms, Riemannian geometry, Frames, Connections, Curvature and torsion, Integration of differential forms.				14
II	Homotopy: Definition and examples, The fundamental group, Homology and Cohomology,Simplical homology, De Rham cohomology.				12
III	Fibre Bundles: The concept of a fibre bundle, Tangent and Cotangent bundles, Vector bundles,principal bundles.				10
IV	Lie Groups and Lie Algebras: Basic concept and examples.				10
	Recommended Books				Year
1	S. Mukhi and N. Mukunda, Lectures on Advanced Mathematical Methods for Physicists, World Sci. Publishers, 2010.				1975
2	S. Mukhi and N. Mukunda, Introduction to Topology, Differential Geometry and Group theory for Physicists, Wiley Eastern Limited,.				1990.
3	C.J. Isham, Modern Differential Geometry for Physicists, World Sci. Publishers.				2001.

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH-635	**Commutative Algebra**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Ideals: Prime, semi-prime, primary, maximal, nil radical and Jacobson radical, Co-maximal ideals and Chinese Remainder Theorem, Primary rings. Modules: Chain conditions, maximal and minimal conditions, Module homomorphisms, exact sequences and tensor products of modules,				12
II	Hom functor, Some basic properties of free modules, and projective modules, Noetherian rings and Hilbert basis theorem, Primary decomposition, Lasker-Noether decomposition theorem, Krull's intersection theorem.				11
III	Applications to principal ideal domains and to Artinian rings, Discrete valuation rings (Examples), Quotient rings. Multiplicative system M in a ring and the quotient ring RM and the ring RP, where P is a prime ideal, Extended and contracted ideal.				11
IV	Integral element, integral extension, integral closure in an over ring, Invertible ideals, fractional ideals, Dedekind domains and their basic properties, Factorization of an ideal in a Dedekind domain.				11
	Recommended Books				Year
1.	Zariski O. and Samuel P, Commutative Algebra, Vol 1, Graduate Text in Mathematics. Springer Verlag.				1975
2.	Atiyah M. F. and Macdonald I. G. Introduction to Commutative Algebra, Addison-Wesley.				1969
3.	Gopalakrishnan N. S. Commutative Algebra, Oxonian Press, New Delhi.				1984
4.	Reid M., Undergraduate Commutative Algebra, London Mathematical Society Student Text Cambridge University Press.				1995

Course Code	Course Title	Lecture 3	Tutorial 1	Practical 0	Credit Hours
MATH-636	**Applied Functional Analysis**				4
Relative Weightage	**IAE 50**	**ETE 50**	**PRE 0**		
Unit	**Contents**				Lectures
I	Normed linear spaces, Banach spaces, linear functionals and operators, Hahn-Banach, Banach-Steinhaus, Open Mapping and Closed Graph Theorems.				12
II	Dual spaces and reflexivity, weak and weak star convergence. Inner product and Hilbert spaces, separability.				11
III	Riesz Representation Theorem, orthonormal sets, projections, adjoint of an operator, self-adjoint, normal and unitary operators, compact operators.				11
IV	Spectral theory of compact self-adjoint operators. Functional analytic approach to some classical problems.				11
	Recommended Books				Year
1.	G. And L.Narici, L. Functional Analysis, Bachman, Academic Press				1996
2.	Conway, J.B., A Course in Functional Analysis, Springer-Verlag				1990
3.	C. and Pedrick G.,First Course in Functional Analysis Goffman, Prentice Hall of India, New Delhi.				1987
4.	P.K, Ahuja,O.P. and Ahmad, K., Functional Analysis, Jain, New Age International(P)Ltd. & Wiley Eastern Ltd., New Delhi.				1997

Course Code	Course Title	Lecture	Tutorial	Practical	Credit Hours
		3	1	0	
MATH637	Analysis				4
Relative Weightage	IAE 50	ETE 50	PRE 0		
Unit	Contents				Lectures
I	The space of linear transformations on R^n to R^m as a metric space, Differentiation of vector-valued function, The Inverse function theorem				14
II	The implicit function theorem, Introduction, Outer measure, Measurable sets and Lebesgue measure, A non-measurable set				12
III	Measurable functions, Littlewood's three principles, The Lebesgue integral of a bounded function over a set of finite measure. The integral of a non-negative function				10
IV	The general Lebesgue integral, Convergence in measure, The general Lebesgue integral, Convergence in measure, Differentiation of monotone functions, Differentiation of an integral. Absolute continuity, Convex functions.				10
	Recommended Books				Year
1	Tom Apostol, Mathematical Analysis: Approach to Advanced Calculus Modern, Narosa Publishing House, New Delhi.				1987
2	Methods of Real Analysis, Goldberg, R.R Oxfor and IHB.				1970.
3	Malik, S.C, Mathematical Analysis, Macmillan and New York, Ed..				1968.
4	Canuto, Claudio, M. Youssuff Hussaini, Alfio Quarteroni, and Thomas A. Zang. Spectral methods. Springer-Verlag, Berlin.				2006.
5	Rudin W. Principles of Mathematical Analysis MCGraw-Hill Inc, 3rd ed.				1983.
6	Kolmogorov A. N. and Fbmin S.V. Introductory Real Analysis, Dover, New York.				1975
7	Shanti Narayan, A Course in Mathematical Analysis, S CHand and Co. Ltd. New Delhi.				1986

Course Code	Course Title **Lecture 3 Tutorial 1 Practical 0**	Credit Hours
MATH-638	**Numerical techniques and its application in differential equations**	4
Relative Weightage	**IAE 50 ETE 50 PRE 0**	
Unit	**Contents**	Lectures
I	Solution of the linear algebraic equations, Thomas Algorithm, elimination process, Newton Raphson method for the solution of multivariable system of algebraic equations, Solution of the initial value problems of system of ordinary differential equations, using Picard's method. Generalized Runge-Kutta methods for a system of differential equations	14
II	Adomian decomposition method, Variational Iteration Method, Homotopy perturbation Methods. Differential transform method	12
III	Method of Weighted residual, Galerkin method, Collocation method, Subdomain method, method of moment, Least square method	10
IV	Spectral Galerkin method, Petro Gelerkin method and its applications in Initial value problem, Boundary value problem, moving boundary problem.	10
	Recommended Books	Year
1	Numerical methods for Engineers and Scientists Joe D. Hoffman Printed In The United States Of America,	2001
2	Debnath, Lokenath, and Dambaru Bhatta. Integral transforms and their applications. Chapman and Hall/CR	2014.
3	Finlayson, Bruce A. The method of weighted residuals and variational principles. SIAM,	2013.
4	Canuto, Claudio, M. Youssuff Hussaini, Alfio Quarteroni, and Thomas A. Zang. Spectral methods. Springer-Verlag, Berlin.	2006.
5	Atluri, Satya N., and S. Shen. The meshless method. Encino, CA: Tech Science Press,	2002.