Master of Science Program in Mathematics

July 2015

Indian Institute of Technology Jodhpur

Master of Science (M.Sc.) Program in Chemistry

Curriculum

Cat.	Course Number	Course Title	L-T-P	Credits	Cat.	Course Number	Course Title	L-T-P	Credits
Semester 1					**Semester 2**				
C	MA511	Linear algebra	3-0-0	3	C	MA521	Abstract Algebra	3-0-0	3
C	MA512	Real analysis	3-0-0	3	C	MA522	Complex Analysis	3-0-0	3
C	MA513	Ordinary Differential equations	3-0-0	3	C	MA523	Partial Differential equations	3-0-0	3
C	MA514	Probability and statistics	3-0-0	3	C	MA524	Numerical Analysis	3-0-0	3
C	MA515*	Programing techniques	3-3-0	4	C	MA525	Functional analysis	3-0-0	3
			Total	**16**				**Total**	**15**
		Summer internship at industry/R&D Labs (Recommend)							
Semester 3					**Semester 4**				
E		Elective	3-0-0	3	E		Elective	3-0-0	3
TH	MA698	Thesis		15	TH	MA698	Thesis		15
			Total	**18**				**Total**	**18**
							Grand total		**67**

Electives

MA551	Topology
MA552	Wavelets analysis and Applications
BL755	Complex Networks
MA553	Dynamical Systems
MA524	Optimization

Note: The students are encouraged to opt electives from B.Tech., M.Tech. and PhD. level courses having mathematical orientation; e.g. Cryptography, Information Theory and Coding, Data Structures and Algorithms, Digital Image Analysis, etc. This will assist in integrating technological aspects into mathematics education.

S. No.	*Category*	*Course Category Title*	*Total Courses*	*Total Credits*
1	C	*Compulsory*	10	31
2	E	*Electives*	2	06
3	TH	Thesis	1	30
			Total	**67**

Course Title	**Linear Algebra**	Course No.	**MA511**
Department	Mathematics	Structure (LTPC)	3-1-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None	To take effect from	

Objectives

To give sufficient knowledge of the subject, which can be used by student for further applications in their respective domains of interest.

Learning Outcomes

1. Concept of linear spaces, mapping between spaces, norm and their action on spaces.
2. Triangularization, diagonalization and Primary decomposition theorem.
3. Semi-simple operators, unitary and normal operators, spectral theory of normal operators.
4. Bilinear forms and Tensor products

Contents

1. Vector Spaces over fields, subspaces, bases and dimension. Direct sum of the sub spaces, System of linear equations, Matrices and rank
2. Linear Transformations, Rank and Nullity theorem, Representation of linear transformations by matrices, duality and transpose.
3. Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, self-adjoint, Unitoary and normal operators, Spectral theorem for normal operators, Rayleigh quotient, Min-Max principle
4. Eigenvalues, Eigenvectors, Characteristic polynomials, minmal polynomials, Cayley Hamilton Theorem, triangulation, diagonalization, Jordan canonical forms, Bilinear forms, symmetric and skew-symmetric bilinear forms, positive definiteness
5. Applications of linear algebra

Reference Books

1. Herstein, I. N. (1975) *Topics in Algebra*, 2nd Edition, John Wiley & Sons
2. Hoffman, K., and Kunze R. (1991) *Linear Algebra*, Prentice Hall of India
3. Lang, S. (2004) *Linear Algebra*, 3rd Edition, Springer Verlag
4. Lax, P. (1997) *Linear Algebra and its applications*, John Wiley & Sons, Indian Edition
5. Sharma, R. K., Shah, S. K. and Shankar, A. G. (2011) *Algebra I: A Basic Course in Algebra*, Pearson Education

Course Title	**Real Analysis**	Course No.	**MA512**
Department	Mathematics	Structure (LTPC)	3-1-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. To train the student in the area of real analysis
2. To give sufficient knowledge of the subject which can be used by student for further applications in their respective domains of interest

Learning Outcomes

1. Metric spaces, compactness, completeness and connectedness
2. Measurability, integrability, Monotone convergence theorem
3. Functions of several variables, inverse function theorem and implicit function theorem

Contents

1. Functions, relations, countable and uncountable sets, axiom of choice, Zorn's lemma,
2. Metric spaces, continuous and uniformly continuous functions, bounded and totally bounded sets, Compactness, Heine-Borel Theorem, Completeness, Cantor's Intersection theorem, Baire spaces, Connectedness, Function spaces, Weierstrass Approximation Theorem.
3. Functions of several variables, continuity, differentiability, partial derivatives, Jacobian, Inverse Function Theorem and Implicit Function Theorem
4. Applications of real analysis

Reference Books

1. Rudin, W. (1976) *Priciples of Mathematical Analysis*, 3rd Edition, McGraw-Hill
2. Aliprantis, C. D., and Burkinshaw, O. (1998) *Principles of Real Analysis*, 3rd Edition, Gulf Professional Publishing
3. Royden, H. L. (1998) *Real Analysis*, 3rd Edition, Macmillan Publishing Company
4. Davidson, K. R. and Donsig, A. P. (2010) *Real analysis and applications: Theory in practice*, Springer Verlag

Course Title	**Ordinary Differential Equations**	Course No.	**MA513**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. Introduce the concepts of existence and uniqueness of solution of differential equations
2. Develop analytical techniques to solve differential equations
3. Understand the properties of solution of differential equations

Learning Outcomes

1. Understanding existence, uniqueness, and other properties of a solution of differential equations
2. Solving differential equations with series method, Green's function method
3. Solving systems of ODE, and characterization of their solutions

Contents

1. *Motivations and origins, Existence-Uniqueness*: Existence of solutions by Picard's method, existence by Perron's method, uniqueness and continuous dependence w.r.t., initial conditions and parameters, continuation of solutions, existence and uniqueness of solutions to system of differential equations, equations of order n.
2. *Second Order Linear Equations*: General solution of homogeneous and non-homogeneous equations with constant coefficients, method of undetermined coefficients, method of variation of parameters, Sturm comparison theorem, Sturm separation theorem, Green's function method, variable coefficients equations, Series solution method, Legendre's equation, Frobenius method, Bessel's equation, Sturm-Liouville problems, orthogonal eigenfunction expansions
3. *Systems of Differential Equations*: Phase plane method, critical points of the system and their stability analysis, algebraic properties of solutions, the eigenvalue-eigenvector method of finding solutions, fundamental matrix solutions, matrix exponential, nonhomogeneous equations.
4. *Applications of differential equations*

Reference Books

1. Ross, S. L. (1989) *Introduction to ordinary differential equations*, 4th Edition, John Wiley & Sons
2. Braun. M. (1983) *Differential Equations and Their Applications*, 3rd Edition, Springer Verlag
3. Coddington, E. A. (1999) *An Introduction to Ordinary Differential Equations*, Prentice Hall of India Learning
4. Chicone, C. (2006) *Ordinary Differential Equations with Applications*, 2nd Edition, Springer Verlag

Course Title	**Probability and Statistics**	Course No.	**MA514**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. Demonstrate an understanding of the basic principles of probability theory.
2. Use of the properties of discrete and continuous random variables with their joint, marginal, and conditional distributions.
3. Use of the various families of probability distributions to model various types of data.
4. Understanding of random sampling, theory of estimation and testing of hypotheses

Learning Outcomes

Understanding of probability theory and statistics to solve industrial problems

Contents

1. Probability measure, conditional probability, Bayes' theorem; Random variable, cumulative distribution function and its properties, probability density function, functions of a random variable, transformation, moments, standard discrete and continuous distributions and their applications, Chebychev's inequality; Random vectors, joint, marginal and conditional distributions, conditional expectation, independence, correlation and regression
2. Bi-variate normal distribution, functions of random vectors, transformation, Convergence of sequences of random variables, weak and strong laws of large numbers, central limit theorems, sampling distributions, estimation of parameters, maximum likelihood method and method of moments, interval estimation, testing of hypotheses, ANOVA
3. Applications of probability and statistics

Reference Books

1. Rohatgi, V. K., and Saleh, A. K. M. E. (2000) *An Introduction to Probability and Statistics*, 2nd Edition, Wiley India
2. Hogg, R. V., McKean J. W., and Craig A. (2006) *Introduction to Mathematical Statistics*, 6th Edition, Pearson Education India
3. Prakasa Rao, B. L. S. (2009) *A First Course in Probability and Statistics*, World Sci entific/Cambridge University Press India
4. Castaneda, L. B., Arunachalam, V., and Dharmaraja, S. (2012) *Introduction to probability and stochastic processes with Applications*, Wiley

Course Title	**Programming Techniques**	Course No.	**MA515**
Department	Mathematics	Structure (LTPC)	3-3-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. To introduce the basics of computer programming.
2. To understand and develop well-structured program in C/C++.

Learning Outcomes

1. Ability to implement programs using C/C++.
2. Ability to implement fundamental data structures in C/C++.

Course Contents

1. *Introduction:* The Von-Neumann architecture, machine language, assembly language, high level programming languages, compiler, interpreter, loader, linker, text editors and flowchart.
2. *Basic features of programming (Using C/C++):* Data types, variables, operators, expressions, control structures, functions, parameter passing conventions.
3. *Advanced features of programming:* Arrays, Multi-dimensional arrays, recursions, operation on data (Insert, delete, search, traverse and modify), structures, memory management, files, input/output, standard library functions, programming tools and pointers, introduction to object oriented programming.

Reference Books

1. Lafore, R. (2002) *Object-Oriented Programming in C++*, 4th Edition, Pearson (Indian Edition)
2. Schildt, H. (2000) *C: The Complete Reference*, 4th Edition, Tata McGraw Hill
2. Gottfried B., and Chhabra, J. (2005) *Programming With C,* Tata McGraw Hill
3. Kernighan, B. W., and Ritchie, D. M., The C Programming Language, Prentice Hall of India
4. Balaguruswamy, E., *Programming in ANSI C,* Tata McGraw-Hill

Course Title	**Abstract Algebra**	Course No.	**MA521**
Department	Mathematics	Structure (LTPC)	3-1-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. To train the student in the domain of Abstract Algebra.
2. To give sufficient knowledge of the subject, which can be used by student for further applications in their respective domains of interest.

Learning Outcomes

1. Modules, Dual modules, Cyclic Primary modules and Decomposition theorem.
2. Nilpotent and Solvable groups, Galois Theory, splitting Fields, Normal extension, Fundamental theorem of Galois theory

Contents

1. Groups and Rings, Transformation Groups, Ploynomial Rings, Principal Ideal Domain, Unique Factorization domain, Prime Fields and Eucledian Algorithm
2. Applications to Abelian groups, Sylow Theory, nilpotent and solvable groups, Galois Theory, splitting Fields, Normal extension, Fundamental Theorem of Galois Theory
3. Applications of algebra

Reference Books

1. Cohn, P. M. (2005) *Basic algebra: Groups, rings and fields*, 2nd Edition, Springer Verlag
2. Artin, M. (2010) *Algebra*, 2nd Edition, Pearson
3. Dummit, D. S. and Foote, R. M. (2004) *Abstract Algebra*, 3rd Edition, Wiley
4. Stewart, I. (2003) *Galois Theory*, 3rd Edition, Chapman and Hall

Course Title	**Complex Analysis**	Course No.	**MA522**
Department	Mathematics	Structure (LTPC)	3-1-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. To train the student in the area of complex analysis
2. To give sufficient knowledge of the subject which can be used by student for further applications in their respective domains of interest

Learning Outcomes

1. Cauchy-Riemann Equations, Homotopy of paths,
2. Cauchy-Goursat theorem and Cauchy's Integral Formula,
3. Evaluation of improper integrals

Contents:

1. Complex functions, continuity, differentiability, Cauchy Riemann Equations, elementary functions, Taylor and Laurent Series expansion, Contour Integration, anti-derivatives of a complex function, Cauchy-Goursat Theorem, Homotopy, Simply and multiply connected domains, Cauchy's Integral formula, Liouville's Theorem, Fundamental Theorem of Algebra, Maximum modulus principle, Residues and poles, Cauchy's residue theorem, Jordan's Theorem, evaluation of Improper integrals, conformal mappings.
2. Applications of complex analysis

Reference Books

1. Lang, S. (1999) *Complex Analysis*, 4th Edition, Springer Verlag
2. Brown, J. W. and Churchill, R. V. (2013) *Complex variables and applications*, 9th Edition, McGraw Hill
3. Ablowitz, M. J., and Fokas, A. S. (2003) *Complex variables: Introduction and applications*, 2nd Edition, Cambridge University Press

Course Title	**Partial Differential Equations**	Course No.	**MA523**
Department	Mathematics	Structure (LTPC)	3-1-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. Introduce the concepts of existence and uniqueness of solution of differential equations
2. Develop analytical techniques to solve differential equations
3. Understand the properties of solution of differential equations

Learning Outcomes

1. Understanding existence, uniqueness, and other properties of a solution of differential equations
2. Solving differential equations with series method, Green's function method, Laplace transform method, and Fourier transform method

Contents

1. *Motivations and origins, PDEs of engineering and physics (Heat, wave and Laplace equations)*
2. *First order partial differential equations*: Linear, quasi-linear and fully nonlinear equations, Lagrange method, the Cauchy problem, Cauchy method of characteristics, compatible systems, Charpit methods
3. *Second order partial differential equations*: Classification and Canonical forms, Adjoint operators, Riemann's method, solving linear partial differential equations with constant coefficients
4. *Elliptic, parabolic and hyperbolic equations*: Laplace/Poisson equation, heat conduction equation, wave equation, Burger equation, Initial and/or boundary value problems, D'Alembert's solution, Maximum-Minimum principles, Duhamel's principle, solutions by Green's function method
5. Applications of partial differential equations

Reference Books

1. Sneddon, I. N. (1986) *Elements of Partial Differential Equations*, McGraw-Hill, New York
2. Prasad, P. and Ravindran, R. (2005) *Partial differential equations*, New Age International Publishers
3. Logan, J. D. (2015) *Applied partial differential equations*, 3rd Edition, Springer Verlag
4. Pinchover, Y. and Rubinstein, J. (2005) *An introduction to partial differential equations*, Cambridge University Press

Course Title	**Numerical Analysis**	Course No.	**MA524**
Department	Mathematics	Structure	3-1-0 [4]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite			

Objectives

1. Learn numerical techniques for variety of mathematical problems
2. Analyze the validity and error in the numerical results

Learning Outcomes

1. Solve numerically algebraic equations, linear systems of equations, ordinary and partial differential equations, eigenvalue problems; Carry out numerical differentiation, integration and interpolation
2. Develop understanding of numerical error and applicability of a particular method

Contents

1. *Errors:* Roundoff errors and truncation errors
2. *Root finding methods:* the bisection method, the method of false position, fixed point iteration method, the Newton-Raphson method, the secant method, Muller's method
3. *Numerical solution of linear system of equations:* Direct methods (Gauss elimination, Gauss-Jordan method, LU decomposition), iterative methods (Gauss Seidel method, Gauss-Jacobi method), matrix inversion, the power method for eigenvalue problems
4. *Interpolation:* Errors in polynomial interpolation, finite differences, Newton's formulae for interpolation, central difference interpolation formulae, Lagrange interpolation formula, Hermite's interpolation formula, Spline interpolation, cubic spline
5. *Numerical integration:* Trapezoidal rule, Simpson's rules, Newton-Cotes integration formulae
6. *Numerical differentiation:* finite difference method, high accuracy differentiation formulas, Richardson Extrapolation
7. Numerical solution of initial value and boundary value problems involving ordinary differential equations: Euler method, midpoint method, Heun's method, Runge-Kutta methods, predictor-corrector methods, finite difference method, shooting method, Finite difference method for solution of partial differential equations
8. Applications of numerical methods

Tools to be used: MATLAB, Mathematica, Octave, Scilab

Reference Books

1. Mathews, J. H. , and Fink, K. D. (2004) *Numerical Methods using MATLAB*, 4th Edition, Prentice Hall
2. Süli, E. and Mayers, D. F. (2003), *An Introduction to Numerical Analysis*, Cambridge University Press
3. Burden, R. L. (2012) *Numerical Analysis*, 9th Edition, Cengage Learning India
4. Conte, S. D., and Boor, C. (1980) *Elementary Numerical Analysis: An Algorithmic Approach*, 3rd Edition, McGraw Hill
5. Chapra, S. C. (2012) Applied Numerical Methods with MATLAB for Engineers and Scientists, 3rd Edition, McGraw Hill

Course Title	**Functional Analysis**	Course No.	**MA531**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Compulsory
Pre-requisite	None		

Objectives

1. To introduce the area of Functional analysis.
2. To give sufficient knowledge of the subject, which can be used by student for further applications in their respective domains of interest.

Learning Outcomes

1. Basic idea of a normed linear spaces and operators on normed linear space.
2. Open Mapping theorem, Hahn-Banach Theorem and their applications.

Contents

1. Normed linear space, Banach space, subspace of a normed linear space, Linear operator, Equivalent norms, norm of a linear operator, boundedness and continuity, quotient spaces, Integrable functions, Lp spaces, Minkowski's inequality, Holder's inequality, separability of Lp spaces, uniformly bounded operator, principle of uniform boundedness, Sub-linear functional, Semi-norm
2. Open mapping theorem, Closed graph theorem, Hahn-Banach Theorem, dual of a normed linear space, reflexive normed linear space, Inner product spaces, polarisation identity, Bessel's inequality, Hilbert space, Riesz representation theorem, operators on Hilbert spaces, compact operators, projections and idempotents.
3. Applications of functional analysis

Reference Books

1. Lax, P. D. (2001) *Functional Analysis*, Wiley Blackwell
2. Limaye, B. V. (1996) *Functional Analysis*, 2nd Edition, New Age International
3. Conway, J. B. (1994) *A course in Functional Analysis*, 2nd Edition, Springer Verlag
4. Goffman, C., and Pedrick, G. (1974) *A First Course in Functional Analysis*, Prentice Hall
5. Taylor A., and Lay, D. (1980) *Introduction to Functional Analysis*, Wiley
6. Kreyszig, E. (2007) *Introductory Functional Analysis with Applications*, Wiley

Course Title	**Optimization Techniques**	Course No.	**MA525**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Elective
Pre-requisite	None		

Objectives

1. To train the student in the domain of linear and non-linear programming
2. To give sufficient tools for solving programming problems which can be used by student for further applications in different areas of interest

Learning Outcomes

1. Simplex method, Charne's M-method, Two-phase Method
2. Duality and Integer programming problem
3. Transportation problem, assignment Problem, Karmakar's Algorithm and Wolf's method
4. Newton's method, Conjugate direction method and Quasi-Newton methods
5. KKT conditions, penalty and Barrier Methods, exact penalty functions

Contents

1. *Linear Programming :* Linear combination of vectors, Convex set, Convex hull, Linear programming problem, feasible solution, basic feasible solution, graphical solution, Simplex method Charne's M method, Two phase method, Solving system of equations and finding inverse of a matrix using simplex method, duality, Complementary Slackness Theorem, Duality and Simplex method, dual simplex algorithm, Integer Programming, Gomory's cut-constraint method, Branch and Bound method, Transportation problem, Assignment problem.
2. *Nonlinear Programming:* First and second order conditions, Iterative methods, line search methods, global convergence of descent algorithms, Newton's method, Conjugate direction method, Quasi-Newton Method, Constrained optimization - Lagrange Multipliers, Karush-Kuhn-Tucker conditions, Regular points, Sensitivity analysis, Quadratic Programming, Convex problems
3. Applications of optimization

Reference Books

1. Luenberger, D. G. (2008) *Linear and Nonlinear Programming*, Yinyu Ye, 3rd Edition, Springer
2. Kambo, N. S. (2005) *Mathematical Programming Techniques*, 2nd Edition, Affiliated East West Press
3. Bazaraa, M. S., Sherali, H.D., and Shetty, C. M. (2006) *Nonlinear Programming: Theory and Algorithms*, 3rd Edition, Wiley
4. Darst, R. (1991) *Introduction to Linear Programming: Applications and Extensions*, Marcel Dekker

Course Title	**Topology**	Course No.	**MA551**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Elective
Pre-requisite	None		

Objectives

1. To train the students in the domain of Topology
2. To give sufficient knowledge of the subject which can be used by student for further applications in their respective domains of interest

Learning Outcomes

1. Topological spaces, order topology and product topology
2. Separation axioms, countability axioms Urysohn's metrization theorem
3. Function spaces, pointwise and uniform convergence, Stone-Weierstrass Theorem. function

Contents

1. Topological spaces, basis and subbasis, order topology, product topology, subspace topology, convergence, closed sets, continuous functions, quotient topology, Connected spaces, Components, local connectedness, compact spaces, limit point compactness, local compactness
2. Countability axioms, separation axioms, normal spaces, Tychonoff spaces, Urysohn's metrization theorem, Tietze extension theorem, Tychonoff theorem, Stone-Cech compactification, Function spaces, pointwise and uniform convergence, compact-open topology, uniform convergence on compact set, Stone-Weierstrass Theorem.
3. Applications of topology

Reference Books

1. Munkres, J. (2000) *Topology*, 2nd Edition, Pearson
2. Willard, S. (2004) *General Topology*, Dover Publications
3. Pervin, W. J. and Boas, R. P. (1964) *Foundations of general topology*, Academic Press
4. Simmons, G. F. (2004) *Introduction to topology and modern analysis*, Tata McGraw Hill
5. Nainpally, S. and Peters, J.(2013) *Topology with Applications: Topological Spaces via Near and Far*, World Scientific

Course Title	**Wavelet Analysis and Applications**	Course No.	**MA552**
Department	Mathematics	Structure (LTPC)	3-0-0 [0]
Offered for	M.Sc. Students	Type	Elective
Pre-requisite	None		

Objectives

1. To introduce the origin of wavelet transform
2. To develop the understanding of multiresolution analysis for different types of signals
3. To equip the students with various possible applications of the wavelet transform

Learning Outcomes

1. Difference between Fourier and wavelet transform.
2. Answer to the question why wavelet transform is a better tool for signal analysis.
3. Implement and apply wavelet transform for various applications.

Contents

1. *Fourier Analysis:* Fourier and inverse Fourier transforms, Gabor transform, short time Fourier transform and the uncertainty principle
2. *Wavelet Analysis:* mother wavelet, orthogonal and biorthogonal wavelets, continuous and discrete wavelet transform, basic properties of wavelet transforms, multiresolution analysis, Haar wavelet transform, Dabuchies Wavelet Transform, wave-packet transform
3. *Applications:* Application of wavelet theory to feature detection, image denoising and compression

Reference Books

1. Chui, C. K. (1992) *An Introduction to Wavelets*, Academic Press
2. Debnath, L. (2002) *Wavelet Transforms and Their Applications*, Birkhauser Verlag
3. Daubechies, I. (1992) *Ten Lectures on Wavelets*, Society for Industrial and Applied Mathematics (SIAM)
4. Akansu, A. N., and Haddad, R. A. (1992) *Multiresolution signal Decomposition: Transforms, Subbands and Wavelets,* Academic Press
5. Kaiser, G. (1995) *A Friendly Guide to Wavelets*, Birkhauser Verlag

Course Title	**Complex Networks**	Course No.	**BL755**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Elective
Pre-requisite			

Objectives

1. To educate and train the students into fundamentals of complex networks and its applications.
2. To provide hands on training along with illustrative examples of real-life systems.

Learning Outcomes

1. Understanding concepts of network and network phenomena in real life
2. Applications of network theory

Course Contents

1. *Introduction to Graph Theory:* Introduction to graph theory, Examples of graphs, Directed and undirected networks, Graph theoretical metrics, Degree distribution, Clustering, Adjacency matrix
2. *Classical random graphs:* Classical models, Loopholes in random graphs, Giant component
3. *Small and large worlds:* Diameter of the Web, Equilibrium versus growing tree, Fractal nature of giant connected component
4. *Diversity of network:* Internet, World-wide web, Cellular networks, Co-occurrence networks,
   *Self-organization of networks: R*andom recursive trees, The Barabasi-Albert model, General preferential attachment, Condensation phenomena
5. *Weighted Networks: T*he strength of weak ties, World-wide airport network, Airport network of India Modeling weighted networks
6. *Motifs, cliques, communities:* Cliques in networks, Statistics of motifs, Modularity, Detecting communities, Hierarchical architecture
7. *Applications of complex networks modeling: E*xamples of real-world networks

References

1. Dorogovtsev, S. N. (2010) *Lectures on Complex Networks*, Oxford University Press
2. Kopos, F. (2007) *Biological Networks*, World Scientific
3. Estrada, E. (2012) *The Structure of Complex Networks*, Oxford University Press

Course Title	**Dynamical Systems**	Course No.	**MA553**
Department	Mathematics	Structure (LTPC)	3-0-0 [3]
Offered for	M.Sc. Students	Type	Elective
Pre-requisite	None		

Objectives

1. To introduce the concept of linear and nonlinear dynamical systems
2. To learn the basic ideas and methods associated with dynamical systems, like, evolution of system, fixed points, periodic points, attractors, bifurcation process and stability of the systems
3. To understand the nonlinearity in nature and study of the nonlinear models in engineering and its dynamics
4. Use Matlab and simulink for solving dissipative dynamical systems which are more relevant to the engineering problems

Learning Outcomes

1. Construction of phase portraits of nonlinear system and understanding of fundamental difference between linear and nonlinear systems.
2. Identification of fixed points, periodic points and limits cycles and determine their stability.
3. Elementary bifurcations like, saddle node, period doubling etc.
4. Concept of attractors, chaotic attractors; measurement of chaos and its application to various engineering models.

Contents

1. History of Dynamics, The importance of being Nonlinear, A Dynamical view of the world, Examples of dynamical systems, Uncoupled Linear systems, Diagonalization, Exponential of operators, Linear systems in R^2 and Stability theory, Nonhomogeneous Linear systems. Nonlinear differential equations, Vector field of nonlinear systems, Phase portrait. Limit cycles and their stability
2. Logistic maps, period doubling bifurcations, Flip and tangent bifurcations, Periodic windows, Intermittency transcritical, Lyapunov exponent, Universality and Experiments, Renormalization, Cantor Set, Two dimensional maps, Bifurcation in two-dimensional maps
3. Lorenz equations, Rossler Equation, Chua's circuit, Forced pendulum. Stable and Unstable manifolds, Basin boundary, Horseshoe maps, Boundary crisis, Interior crisis, Statistics of Chaotic attractor, Frequency spectra of orbits, Matrix times circle, Dynamics on a Torus, Analysis of a chaotic Time series
4. Lyapunov function and Central Manifold theory, Non-smooth bifurcations, bifurcation in piecewise smooth 2-dim map, multiple attractor bifurcation
5. Application of dynamical systems

Reference Books

1. Steaven, S. (2007) *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*, Levant Books
2. Devaney, R. L. (2005) *An Introduction to Chaotic Dynamical Systems*, Addison Wesley
3. Alligood, K., Sauer, T., and Yorke, J. (2008) *Chaos: An Introduction to Dynamical Systems*, 2nd Edition, Springer Verlag

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Course Booklet for M.Sc. (Mathematics)

2015