



भारतीय प्रौद्योगिकी संस्थान हैदराबाद  
Indian Institute of Technology Hyderabad

**Proposal  
On  
2 year M.Sc. (Mathematics)  
&  
M.Sc. (Mathematics & Computing) Programs**

**Department of Mathematics  
Indian Institute of Technology Hyderabad  
Yeddumailaram 502205, Andhra Pradesh, INDIA**

**Proposal for 2 year M.Sc. (Mathematics)  
&  
M.Sc. (Mathematics & Computing) Programs**

**Department's Vision:**

The Department of Mathematics at IIT Hyderabad aims at becoming a centre for applicable and interdisciplinary research that complements and supplements the expertise extant in and around Hyderabad.

**Course Objective:**

To produce students with good mathematical background for research in Mathematics, Mathematics & Computing streams.

**Targeted Students:**

Bachelor's degree with Mathematics as one of the core subjects

**Important features of the programs:**

- Students are given freedom to pursue M.Sc. in **Mathematics** or in **Mathematics & Computing** depending on their interest right from the second semester.
- Emphasis is on **building firm foundational knowledge** on the mathematical principles required for higher and rigorous research both in Mathematics and Mathematics & Computing.
- Successful students will be able to pursue both **Academic** and **Industrial Research**.
- The course, as it stands envisaged, does not compromise on the Mathematical rigor and the course content and structure will be so **designed** that at the end of 3 semesters the students will be taught all the necessary topics required to appear **for the CSIR–JRF/GATE/NBHM** examinations.
- Enough emphasis on student seminars/viva and hands on training.

**Details of the Program:**

- 11 core and 1 compulsory Lab (Computing) courses for all students.
- 2 core advanced courses for M. Sc. students in 4th semester from Mathematics or Mathematics & Computing streams.
- 3 core electives + 1 free elective
- Of the 4 electives + 2 core advanced courses, if a student chooses at least 4 courses from the basket of **Mathematics** courses, then he/she will be awarded 'M.Sc. in Mathematics' (Similarly, if the courses are from the basket of **Mathematics & Computing**, then the degree to be awarded is 'M.Sc. in Mathematics & Computing').

**M.Sc. (Mathematics) and M.Sc. (Mathematics & Computing)**

<b>Semester I</b>		<b>Semester II</b>		<b>Semester III</b>		<b>Semester IV</b>	
Analysis of Functions of a Single Variable	3	Complex Analysis	3	Analysis of Functions of Several Variables	3	Advanced Course-I	3
Linear Algebra	3	Elements of Groups and Rings	3	Functional Analysis	3	Advanced Course-II	3
Ordinary Differential Eqns	3	Measure and Integration	3	Partial Differential Eqns	3	Elective III	3
Probability Theory	3	Combinatorics and Graph Theory	3	Elective II	3	Elective IV	3
Basics of Programming	3	Elective I	3	Thesis I	6	Thesis II	6
<b>Total</b>	<b>15</b>		<b>15</b>		<b>18</b>		<b>18</b>
4 Core + 1 Lab		4 Core + 1 Elec		3 Core + 1 Elec + 1 Thesis		2 Core + 2 Elec + 1 Thesis	

## **MA 4010: Analysis of Functions of a Single Variable**

Real number system: Field properties, ordered properties, completeness axiom, Archimedean property, subsets of  $\mathbb{R}$ , infimum, supremum, extended real numbers. Finite, countable and uncountable sets, decimal expansion.

Sequences of real numbers, Subsequences, Monotone sequences, Limit infimum, Limit Supremum, Convergence of Sequences .

Metric spaces, limits in metric spaces. Functions of single real variable, Limits of functions, Continuity of functions, Uniform continuity, Continuity & compactness, Continuity and connectedness, Monotonic functions, Limit at infinity.

Differentiation, Properties of derivatives, Chain rule, Rolle's theorem, Mean-value theorems, L'Hospital's rule, Derivatives of higher order, Taylor's theorem.

Definition and existence of Riemann integral, properties, Differentiation and integration.

Revision of Series, Sequences and Series of functions, Pointwise and uniform convergence, Uniform convergence of continuous functions, Uniform convergence and differentiability, Equicontinuity, Pointwise and uniform boundedness, Ascoli's theorem, Weierstrass approximation theorem, Fourier series.

### **References:**

- W. Rudin, Principles of Mathematical Analysis, McGraw-Hill international editions (Math Series), 3rd Edition, **1976**.
- S.R. Ghorpade and B.V. Limaye. A course in calculus and real analysis. Undergraduate Texts in Mathematics. Springer, New York, Springer International Ed., New Delhi, **2006**.
- R.R. Goldberg, Methods of Real Analysis, Oxford & IBH Publishing Co. Pvt Ltd, **1970**.
- Kenneth A. Ross, Elements of Analysis: The Theory of Calculus, Springer Verlag, UTM, **1980**.

## **MA 4020: Linear Algebra**

System of Linear Equations, Elementary Operations, Row-Reduced Echelon Matrices, Gaussian Elimination.

Vector Spaces, Subspaces, Direct Sums, Bases and Dimension, Linear Maps, Rank-Nullity Theorem, The Matrix of a Linear Map, Invertibility.

Eigenvalues and Eigenvectors, Invariant Subspaces, Upper-Triangular Matrices, Diagonal Matrices.

Inner Products, Norms, Orthonormal Bases, Gram-Schmidt process, Schur's theorem, Orthogonal Projections and Minimization Problems, Linear Functionals and Adjoints.

Self-Adjoint and Normal Operators, The Spectral Theorem for finite dimensional operators.

Generalized Eigenvectors, The Characteristic Polynomial, Cayley-Hamilton Theorem, The Minimal Polynomial, Jordan Form.

#### **References:**

- Sheldon Axler, "Linear Algebra Done Right", University Press, **2010**.
- K. Hoffman and R. Kunze, "Linear Algebra", PHI Learning, Second Edition, **2009**.
- Gilbert Strang, Linear algebra and its applications, Thomson Brooks/Cole, Fourth Edition **2006**.
- Friedberg H. Stephen, Insel J. Arnold, Spence E. Lawrence, "Linear Algebra" PHI Learning, Fourth Edition **2009**.

### **MA 4030: Ordinary Differential Equations**

Mathematical Models, Review of methods, First Order Equations, Existence, Uniqueness and continuity theorems, separation and comparison theorems. Higher order equations, Solutions in Power Series, Legendre equation, Bessel equation, generating functions, orthogonal properties,

System of differential equations, existence theorems, Homogeneous linear systems, Nonhomogeneous linear systems, linear systems with constant coefficients.

Two point boundary value problem, Green's functions, construction of Green's functions, Sturm-Liouville problems, Eigen values and Eigen functions.

Autonomous systems, Stability of linear systems with constant coefficients, Linear plane autonomous systems.

#### **References:**

- G. F. Simmons, Ordinary Differential Equations with Applications and Historical Notes. Tata McGraw Hill Edition, **2003**.
- G.F. Simmons and S.G. Krantz, Differential Equations Theory, Technique and Practice. (The Walter Rudin Student Series in Advanced Mathematics). Tata McGraw Hill Edition, **2006**.
- E.A. Coddington, An Introduction to Ordinary Differential Equations, Prentice-Hall, Englewood Cliffs, N.J., **1961**.

### **MA 4040: Probability Theory**

Probability Space, Independence and dependence, Random variables and distribution functions

Random variables and joint distributions, Functions of random variables

Expectation and moments, Conditional expectation, Characteristic functions, Sequences of random variables

Modes of Convergence, Weak and Strong laws of large numbers, Central Limit Theorems.

#### **References:**

- Sheldon M. Ross, "A first course in Probability," Prentice-Hall, 6ed, **2001**.
- P. Meyer, "Introductory probability and statistical applications," Oxford & IBH Publishing Co. PVT Ltd, **1970**.
- P. Billingsley, "Probability & Measure," Wiley, **2012**.

### **MA 4051: Basics of Programming**

Structure of a program, Input and Output Variables and Types, Arithmetic and Relational Operators, Control Structures, Functions, Arrays and Pointers, File Handling.

#### **References:**

- Bruce Eckel, "Thinking in C++", Pearson Education India, **2000**.
- B. Kernighan & D. Ritchie, "C Programming Language", Prentice Hall, **1988**.
- Stanley B Lippman, "C++ Programing Primer", Addison-Wesley, **2012**.

### **MA 4060: Complex Analysis**

Spherical representation of extended complex plane, Analytic Functions, Harmonic Conjugates, Elementary Functions, Cauchy Theorem and Integral Formula, Homotopic version

Linear fractional transformations, Power Series, Analytic Continuation and Taylor's theorem, Zeros of Analytic functions, Hurwitz Theorem, Maximum Modulus Theorem, Laurent's Theorem, Classification of singularities

Residue theorem and applications, Argument Principle, Theorem of Rouché, Schwarz-Christoffel Transformation.

#### **References:**

- J.W. Brown, R.V. Churchill, Complex Variables, McGraw Hill, 8th Edition, **2010**.
- J. B. Conway, Functions of one Complex Variables, Springer, 2nd Edition, **1978**.
- L. Ahlfors, Complex analysis, Mc Graw Hill, **1979**.

- A.R. Shastri, Basic Complex Analysis of one variable, Mc Millan, New Delhi, **2011**.

### **MA 4070: Elements of Groups and Rings**

Binary operation and its properties, Definition of Groups, Examples and basic properties. Subgroups, Coset of a subgroup, Lagrange's theorem. Cyclic groups. Normal subgroups, Quotient group. Homomorphisms, Isomorphism theorems. Permutation groups, Cayley's theorems. Direct and semidirect product of groups. Group actions and Sylow theorems.

Definition of Rings, Examples and basic properties, Zero divisors, Integral domains, Fields, Characteristic of a ring, Quotient field of an integral domain. Subrings, Ideals, Quotient rings, Isomorphism theorems. Ring of polynomials. Prime, Irreducible elements and their properties, Unique Factorization Domains, Principal Ideal Domains, and Euclidean domains. Prime ideal, Maximal ideal, Prime avoidance theorem, Chinese remainder theorem.

#### **References:**

- D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley & Sons Inc, 3rd Edition. **2004**.
- I. N. Herstein, Topics in Algebra, Wiley India Pvt Ltd, 2nd Edition, **2006**.
- Artin, M., Algebra, Prentice Hall of India, **1994**.
- Jacobson, N., Basic Algebra I, Hindustan Publishing Corporation, 2nd Edition, **1991**.

### **MA 4080: Measure and Integration**

#### **Prerequisite: MA 4010**

Sigma-algebra of measurable sets. Completion of a measure. Lebesgue Measure and its properties. Non-measurable sets.

Measurable functions and their properties. Integration and Convergence theorems. Lebesgue integral, Functions of bounded variation and absolutely continuous functions. Fundamental Theorem of Calculus for Lebesgue Integrals.

Product measure spaces, Fubini's theorem.

$L_p$  spaces, duals of  $L_p$  spaces. Riesz Representation Theorem for  $C([a,b])$ .

#### **References:**

- H. L. Royden, Real analysis. Third edition. Macmillan Publishing Company, New York, **1988**.

- W. Rudin, Real and complex analysis. Third edition. McGraw-Hill Book Co., New York, **1987**.
- K. R. Parthasarathy, Introduction to Probability and Measure, TRIM Series, Vol .33, Hindustan book agency, New Delhi, **2005**.
- Krishna B.Athreya and S. Lahiri, Measure theory and probability theory. Springer Texts in Statistics, Springer Verlag, **2006**.

### **MA 4090 : Combinatorics and Graph Theory**

Basic counting: Bijections, Counting objects with repetitions, de Bruijn-Erdos theorem, Listing combinatorial objects.

Permutations: Combinatorial representation of a permutation, Descents and Eulerian polynomial, Tree representation for permutations.

Inclusion-Exclusion principle: Use of Rook polynomial, Some arithmetic and Mobius functions.

Parity: Parity in Graph theory, Eulerian circuits in graphs, digraphs and de Bruijn circuits, Hypercubes and Gray codes, Parity of a permutation, Quadratic reciprocity.

Pigeonhole principle: Ramsey theorem, The infinite case.

Geometry: Regular polytopes and tessellations of plane, triangulations and Sperner's lemma.

Recurrence relations: Fibonacci recurrence relation, Linear homogeneous recurrence relations with constant coefficients, Case of repeated roots, Difference tables and sums of polynomials, Other types of recurrence relations.

#### **References:**

- Tremblay and Manohar, Discrete Mathematics Structures with Applications to Computer Science, McGraw Hill, **1997**
- Sharad S. Sane, Combinatorial Techniques, Texts and Reading in Mathematics, Hindustan Book Agency, **2013**.
- Liu and Mohapatra, Elements of Discrete Mathematics, Tata McGraw Hill, **2008**.

### **MA 5010: Analysis of functions of several variables**

**Prerequisite: MA 4010**

Functions of several-variables, Directional derivative, Partial derivative, Total derivative, Jacobian, Chain rule and Mean-value theorems, Interchange of the order of differentiation, Higher derivatives, Taylor's theorem, Inverse mapping theorem, Implicit function theorem, Extremum problems, Extremum problems with constraints, Lagrange's multiplier method.

Multiple integrals, Properties of integrals, Existence of integrals, iterated integrals, change of variables. Curl, Gradient, div, Laplacian cylindrical and spherical coordinate, line integrals, surface integrals, Theorem of Green, Gauss and Stokes.

**References:**

- Apostol T.M., Mathematical Analysis; Narosa Book Distributors Pvt Ltd, **2000** .
- Jerrold E. Marsden, Anthony Tromba, Alan Weinstein, Basic multivariable analysis, Springer Verlag **1993**.
- Ghorpade, Sudhir R.; Limaye, Balmohan V. A course in multivariable calculus and analysis. Undergraduate Texts in Mathematics. Springer, *New York*, Springer International Edition, New Delhi, **2010**.
- Fleming, Wendell Functions of several variables. Second edition. Undergraduate Texts in Mathematics. Springer-Verlag, *New York-Heidelberg*, **1977**.
- J.E. Marsden, A. Tromba, and A.Weinstein, Basic Multivariable Calculus, Springer-Verlag, **1992**.

**MA 5020: Functional Analysis****Prerequisites: MA 4010, MA 4020**

Normed linear spaces. Non-compactness of the unit ball in infinite dimensional normed linear spaces. Product and quotient spaces. Banach spaces, Hilbert spaces.

Linear maps. Boundedness and continuity. Linear isometries, linear functionals. Examples.

Hahn-Banach extension theorem, applications. Banach-Steinhaus theorem, closed graph theorem, open mapping theorem and bounded inverse theorem, Spectrum of a bounded operator.

Gram-Schmidt orthogonalization. Bessel's inequality, Riesz-Fisher theorem. Orthonormal basis, Parseval's identity, Projection, orthogonal decomposition. Bounded linear functionals on Hilbert spaces.

### References:

- B.V. Limaye, Functional Analysis, Second edition, New Age International, New Delhi, **1996**.
- J. B. Conway, A Course in Functional Analysis, Second edition, Graduate Texts in Mathematics, Vol. 96, Springer, **1990**.
- E. Kreyszig, Introductory Functional Analysis with Applications. John Wiley & Sons, **1978**.
- P. D. Lax, Functional Analysis. Wiley-Interscience, **2002**.
- B. Bollabas, Linear Analysis, An Introductory Course. Cambridge Mathematical Textbooks, **1990**.

## MA 5030: Partial Differential Equations

### Prerequisite: MA 4030

First order partial differential equations:

Surfaces and Curves, Classification of 1st order p.d.e. Classification of solutions- Pfaffian differential equations - Quasi-linear equations, Lagrange's method-compatible systems-Charpit's method- Jacobi's method-Integral surfaces passing through a given curve- method of characteristics for quasi-linear and non-linear p.d.e., Monge cone, characteristic strip.

Second order partial differential equations:

Origin of second order p.d.e's - classification of second order p.d.e's. Wave equation - D'Alemberts' solution - vibrations of a finite string - existence and uniqueness of solution - Riemann method. Laplace equation - boundary value problems, Uniqueness and continuity theorems - Dirichlet problem for a circle - Dirichlet problem for a circular annulus - Neumann problem for a circle - Theory of Green's function for Laplace equation. Heat equation - Heat conduction problem for an infinite rod - Heat conduction in a finite rod - existence and uniqueness of the solution.

### References:

- John F., Partial Differential Equations, 2nd Edition, Springer-Verlag. **1981**.
- Ian Sneddon, Elements of Partial Differential Equations, Dover Publications, **2006**.
- Tyn MynT, U., and Loknath Debnath: Partial Differential Equations for Scientists and Engineers, North Holland Publisher, 3rd Edition, **1987**.
- Zachmanoglou, E.C. and Thoe, D.W., Introduction to Partial Differential Equations with Applications. Dover Publications, **1987**.

## **List of Electives**

### **MA 5040: Topology**

Definition of Topologies in terms of open sets, neighborhood system, closed sets and closure operations and their equivalence, points of accumulation, interior, exterior and boundary points.

Base and subbase of a topology, subspace, product space, quotient space, continuous, open and closed maps, homeomorphism convergence of sequence and nets.

Separation axioms, Urysohn's Lemma, Tietze extension theorem, separability.

Compactness, local compactness, sequential and countable compactness, Tychonoff's theorem, Lindelof space. One point compactification

Connectedness and local connectedness.

Urysohn's metrization theorem.

#### **References:**

- J. R. Munkres. Topology: a first course. Prentice-Hall, Inc., Englewood Cliffs, N. J., **1975**.
- J. Dugundji, Topology. Reprinting of the 1966 original. Allyn and Bacon Series in Advanced Mathematics. Allyn and Bacon, Inc., Boston, Mass.-London-Sydney, **1978**.
- Joshi, K. D. Introduction to general topology. John Wiley & Sons, Inc., New York, **1983**.
- Kelly, J. L. General topology. Graduate Texts in Mathematics, No. 27. Springer-Verlag, New York-Berlin, **1975**.

## **MA 5050 : Mathematical Methods**

Integral Transforms:

Laplace transforms: Definitions - properties - Laplace transforms of some elementary functions - Convolution Theorem - Inverse Laplace transformation - Applications.

Fourier transforms - Definitions - Properties - Fourier transforms of some elementary functions - Convolution theorems - Fourier transform as a limit of Fourier Series - Applications to PDE.

Integral Equations:

Volterra Integral Equations: Basic concepts - Relationship between Linear differential equations and Volterra integral equations - Resolvent Kernel of Volterra Integral equation - Solution of Integral equations by Resolvent Kernel - The Method of successive approximations - Convolution type equations, solution of integral differential equations with the aid of Laplace transformation.

Fredholm Integral equations: Fredholm equations of the second kind, Fundamentals – Iterated Kernels, Constructing the resolvent Kernel with the aid of iterated Kernels - Integral equations with degenerate Kernels - Characteristic numbers and eigen functions, solution of homogeneous integral equations with degenerate Kernel - non homogeneous symmetric equations - Fredholm alternative.

Calculus of Variations:

Extrema of Functionals: The variation of a functional and its properties - Euler's equation - Field of extremals - sufficient conditions for the Extremum of a Functional conditional Extremum Moving boundary problems - Discontinuous problems - one sided variations - Ritz method.

References:

- J W Brown and R V Churchill: Fourier Series and Boundary Value Problems, McGraw Hill, 8th Edition, **2011**.
- A Chakraborty: Applied Integral Equations, Tata McGraw Hill, **2008**.
- F G Tricomi: Integral Equations, Dover Publications, **1985**.

## **MA 5060: Numerical Analysis**

Floating point representation of numbers, floating point arithmetic, errors, propagation of error

Solution of nonlinear equations: Iterative methods, Fixed point iteration method, convergence of fixed point iteration, Newton-Raphson method, complex roots and Muller's method.

Interpolation: Existence and uniqueness of interpolating polynomial, error of interpolation - interpolation of equally and unequally spaced data - Inverse interpolation - Hermite interpolation.

Approximation: Uniform approximation by polynomials, data fitting, Least square, uniform and Chebyshev approximations

Solution of linear systems: Direct and iterative methods, ill-conditioned systems, Eigen values and eigen vectors: Power and Jacobi methods.

Integration: Newton-cotes closed type methods; particular cases, error analysis - Romberg integration, Gaussian quadrature; Legendre, Chebyshev formulae.

Solution of Ordinary differential equations: Initial value problems: Single step methods; Taylor's, Euler method, modified Euler method, Runge-Kutta methods, error analysis.

#### **References:**

- S D Conte and Carl de Boor: Elementary Numerical Analysis, An Algorithmic Approach. McGraw Hill International Edition 3rd Ed. **1980**.
- F B Hildebrand: Introduction to Numerical Analysis, Dover Publications, 2nd Ed. **2008**.
- K. D. Atkinson: Elementary Numerical Analysis, John Wiley & Sons, 3rd Edition, **2009**.

### **MA 5070: Modules and Fields**

Review of Rings, Modules, Free modules, Cartesian products and direct sums of modules, quotient modules, Simple and semisimple modules, isomorphism theorems. Modules over principal ideal domains and applications. Noetherian and Artinian rings/Modules, Hilbert basis theorem. Jordan-Holder theorem. Projective/Injective modules.

Field extensions. Algebraic/transcendental elements, Algebraic extensions. Finite fields, Cyclotomic fields. Splitting field of a polynomial. Algebraic closure of a field, Uniqueness. Normal, separable, purely inseparable extensions. Primitive elements, simple extensions. Fundamental theorem of Galois theory. Solvability by radicals – Solutions of cubic and quartic polynomials, Insolubility of quintic and higher degree polynomials. Geometric constructions.

#### **References:**

- D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley & Sons Inc, 3rd Edition. **2004**.

- C. Musili, Introduction to Rings and Modules, Narosa Publishing House, New Delhi **1994**.
- S. Lang, Algebra, 3rd Edition, Springer-Verlag (India), **2004**.
- Jacobson, N., Basic Algebra II, Hindustan Publishing Corporation, **1991**.

### **MA 5080: Advanced programming**

Mathematical background, Model – What to Analyze, Abstract Data Types (ADT's), The List ADT, The Queue ADT, The Stack ADT, Preliminaries, Binary Trees, The Search Tree ADT, Binary Search Trees, AVL Tree, Preliminaries, Insertion Sort, Shell Sort, Merge Sort, Quick Sort, Definitions, Topological Sort and Minimal Spanning Tree.

#### **References:**

- Mark Allen Weiss, "Data Structures and Algorithm Analysis in C++", Pearson Education (India), 3<sup>rd</sup> Edition, **2007**.
- Jean-Paul Tremblay and Richard B. Bunt, "Introduction to Computer Science, An Algorithmic Approach", McGraw Hill, Second edition, **1988**.
- Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, "Introduction to Algorithms", MIT Press, Third edition, **2009**.

### **MA 5090 : Sets, Logics and Boolean Algebra**

Sets and Relations: Types of relations, Peano Axioms and Mathematical Induction, Cardinality, Recursion.

Boolean Algebra: Partially Ordered Sets, Lattices, Subalgebras, Direct Product, Homomorphisms, Boolean Functions, Representation and Minimization of Boolean functions.

Mathematical Logic: Connectives, Normal Forms, Theory of Inference for the Statement Calculus.

#### **References:**

- J. P. Trembley and R. Manohar, "Discrete Mathematical Structures with Applications", Tata McGraw-Hill, **2009**.
- R. L. Causey, "Logic, Sets and Recursion", 2nd Ed. Jones and Bartlett, **2010**.
- A. Singh, "Logics for Computer Science", PHI, **2004**.

- G. Birkhoff and S. MacLane, "A Survey of Modern Algebra", Mc Millan Publishers, 4th Ed, **1977**.
- S. Givant and P. Halmos, "Introduction to Boolean Algebras", Springer, **2009**.

#### **Further list of Electives:**

- Operator theory
- Banach space theory
- Representation theory
- Time-Frequency Analysis
- Topological Dynamics
- Wavelet Analysis
- Galois theory
- Commutative Algebra
- Algebraic Number theory
- Advanced Complex Analysis
- Fluid Mechanics
- Convex functions and their applications
- Algebraic geometry
- Differential Geometry
- Mathematics behind machine learning
- Convex Optimization
- Fuzzy sets: Theory and applications
- Reasoning under uncertainty

#### **List of Advanced Courses**

##### **MA 5100: Introduction to Algebraic Topology**

##### **Prerequisites: MA 5040**

Homotopy, Fundamental group, The Fundamental group of the circle, Retractions and fixed points, Application to the Fundamental Theorem of Algebra, The Borsuk-Ulam theorem, Homotopy equivalence and Deformation retractions, Fundamental group of a product of spaces, and Fundamental group the torus, Sphere, and the real projective n-space.

Free Products of Groups, The Van Kampen Theorem, Fundamental Group of a Wedge of Circles, Definition and construction of Cell Complexes, Application to Van Kampen Theorem to Cell Complexes, Statement of the Classification Theorem for Surfaces, Fundamental groups of the closed orientable surface of genus  $g$ .

Introduction to Covering spaces, Universal Cover and its existence, Unique Lifting Property, Galois Correspondence of covering spaces and their Fundamental Groups, Representing Covering Spaces by Permutations - Deck Transformations, Group Actions, Covering Space Actions, Normal or Regular Covering Spaces.

## References:

- J. R. Munkres, Topology, 2nd Edition, Pearson Publishing Inc, **2000**.
- J. R. Munkres, Elements of Algebraic Topology, Westview Press, **1996**.
- A. Hatcher, Algebraic Topology, Cambridge University Press, **2002**.
- M. A. Armstrong, Basic Topology, Springer International Edition, **2004**.
- W. S. Massey, Algebraic Topology: An Introduction , Springer, **1977**.
- J. J. Rotman, An Introduction to Algebraic Topology, Springer, **1988**.

## MA 5110 : Fourier Analysis and Applications

### Prerequisites: MA 4010

Definition, Examples, Uniqueness of Fourier series, Convolution, Cesaro summability and Abel summability of Fourier series, Mean square convergence of Fourier series, A continuous function with divergent Fourier series. Some applications of Fourier series, The isoperimetric inequality, Weyl's equidistribution theorem.

Fourier transform on the real line and basic properties, The Schwartz space, Approximate identity using Gaussian kernel, Solution of heat equation, Fourier inversion formula,  $L^2$ -theory .

Some basic theorems of Fourier Analysis, Poisson summation formula, Heisenberg uncertainty principle, Hardy's theorem, Paley-Wiener theorem, Wiener's theorem, Shannon sampling theorem.

The class of test functions, Distributions, Convergence, differentiation and convolution of distributions, Tempered distributions, Fourier transform of a tempered distribution.

## References:

- Bhatia, Rajendra. Fourier series. Texts and Readings in Mathematics. Hindustan Book Agency, New Delhi, **1993**.
- Chandrasekharan, Komaravolu. Classical Fourier transforms. Universitext. Springer-Verlag, Berlin, **1989**.
- Katznelson, Yitzhak. An introduction to harmonic analysis. Third edition. Cambridge Mathematical Library. Cambridge University Press, Cambridge, **2004**.
- Stein, Elias M.; Shakarchi, Rami. Fourier analysis. An introduction. Princeton Lectures in Analysis, 1. Princeton University Press, Princeton, NJ, **2003**.

## MA 5120: Numerical Linear Algebra

**Prerequisites: MA 4020**

Gaussian elimination and its variants. Sensitivity of system of linear systems. QR factorization and The least squares. The singular value decomposition. Computing Eigenvalues and Eigenvectors. Iterative methods for linear systems.

**References:**

- Lloyd N. Trefethen, David Bau III, "Numerical Linear algebra", SIAM, **1997**.
- Gene H. Golub, Charles F. Van Loan, "Matrix computations", Hindustan Book Agency, 3rd edition, **2007**.
- Alston S. Householder, "The theory of matrices in Numerical Analysis", Dover **1964**.
- J. W. Demmel, "Numerical Linear Algebra", SIAM, **1996**.

**MA 5130: Theory of Computation**

Regular Languages: Finite Automata, Non-determinism, Regular Expressions, Nonregular Languages.

Context-Free Languages: Context-free Grammars, Pushdown Automata, Non-context-free Languages

The Church-Turing Thesis: Turing Machines and Variants.

Decidability: Decidable Languages, The Halting Problem.

Reducibility: Undecidable Problems, Example, Mapping Reducibility

Time Complexity: Measuring Complexity, The classes of P and NP.

**References:**

- Michael Sipser, Theory of Computation, Cengage Learning, **2007**.
- J. E. Hopcroft, R. Motwani, J. D. Ullman, Introduction to Automata Theory, Languages, and Computation, Addison Wesley, **2000**.
- P.Linz, Introduction To Formal Languages And Automata, Narosa Pub. **1997**.
- Gyorgy E Revesz, Introduction To Formal Languages, Mcgraw-Hill Book Co., **1985**.

**MA5980: M.Sc Thesis-1**

**MA5990: M.Sc Thesis-2**