M.Sc. Mathematics

The M.Sc. Mathematics programme, offered by the Department of Mathematics, blends of pure mathematics, applied mathematics and basic computer science. This programme covers theoretical, computational and practical aspects of mathematics. In the curriculum, the core mathematics courses are designed to build a strong foundation in the subject, the laboratory based courses provide the exposure and training in application-oriented practical subjects.

Objective of the Programme:

The M.Sc. Mathematics programme aims to prepare students with a deep understanding of mathematical concepts, research oriented attitude and skill of application of mathematical and computational tools and techniques in formulation and solution of real world problem. It is specially designed to prepare students for a successful career in academic institution, research institution and industry.

Programme Outcome:

By the end of 2-year M.Sc. Mathematics programme, students will be able to communicate mathematical ideas with clarity and coherence, both written and verbally. They will be able to conduct independent research in specialized areas of mathematics, teach courses in mathematics or subjects with high mathematical content at school and college level, and work in industry involving applications of mathematics.

M. Sc. Mathematics

Semester-Wise Scheme and Syllabus
(2019-2020 to Onward)

Semester – I

S. No.	Course Code	Course Title	Type of Course (C/E)	L	T	P	Credits
1	MSM411	Abstract Algebra	C	3	1	0	4
2	MSM412	Real Analysis	C	3	1	0	4
3	MSM413	Probability and Mathematical Statistics	C	3	1	0	4
4	MSM414	Mathematical Programming	C	3	1	0	4
5	MSM415	Ordinary Differential Equations	C	3	1	0	4
Total				15	5	0	20

Semester – II

S. No.	Course Code	Course Title	Type of Course (C/E)	L	T	P	Credits
1	MSM421	Linear Algebra	C	3	1	0	4
2	MSM422	Complex Analysis	C	3	1	0	4
3	MSM423	Topology	C	3	1	0	4
4	MSM424	Partial Differential Equations	C	3	1	0	4
5	MSM425	Elective Paper	E	3	0	1	4
Total				15	4	1	20

Semester – III

S. No.	Course Code	Course Title	Type of Course (C/E)	L	T.	P	Credits
1	MSM531	Functional Analysis	C	3	1	0	4
2	MSM532	Numerical Analysis	C	3	1	0	4
3	MSM533	Measure Theory and Integration	C	3	1	0	4
4	MSM534	Elective Paper	E	3	1	0	4
5	MSM535	Elective Paper	E	3	1	0	4
Total				15	5	0	20

Semester – IV

S. No.	Course Code	Course Title	Type of Course (C/E/OE)	L	T	P	Credits
1	MSM541	Mathematical Modeling	C	3	1	0	4
2	MSM542	Dynamics of Rigid Body	C	3	1	0	4
3	MSM543	Elective Paper	E	3	1	0	4
4	MSM544	Open Elective Paper	OE	3	1	0	4
5	MSM545	Open Elective Paper	OE	3	1	0	4
Total				15	5	0	20

Note- IMM: Integrated M.Sc. in Mathematics; Numeric (xyz) in paper/course code: x-Level of Course, y- Semester, z- Paper/Course Number; C- Compulsory/Core Course; E- Elective, O/OE- Open Elective; 15L- 15 Lectures; LTP: Lecture-Tutorial-Practical.

Course Code **MSM411**

Course Name **ABSTRACT ALGEBRA**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: This course contains topics of groups and rings. The course introduces the concepts of groups and ring.

Learning Outcomes: Students will learn to construct and describe groups. They will learn the properties of groups and get familiar with important classes of groups. They will become familiar with rings and their arithmetic.

Course Details:

Unit-I: Review of groups and properties, First and second Isomorphism theorems, Conjugacy relation, Group Action, Equivalent formulation of action as a homomorphism of G to Symmetric group, Stabilizer (Isotropy) subgroups and Orbit decomposition, Class equation of an action, Conjugacy class equation, Transitive actions, core of a subgroup. **(15L)**

Unit-II: Sylow subgroups, Sylow's Theorem I, II and III, p-groups and applications, Direct and inverse images of Sylow subgroups, Commutator subgroup, Normal and subnormal series, composition series, Jordan-Holder theorem. Solvable groups, Simple groups, simplicity of An. **(15L)**

Unit-III: Review of Rings and properties, Left and right ideal, prime ideals, maximal ideals, Prime and irreducible elements, Greatest Common divisor, Least Common Multiple, Euclidean domains, Maximal and prime ideals, Principal ideal domains, Divisor chain condition, Unique factorization domains, Examples and counterexamples, Chinese remainder theorem for rings and PID's, Polynomial rings over domains, Unique factorization in polynomial rings over UFD's. **(15L)**

Recommended Readings:

1. Herstein I. N., 1964, *Topics in algebra*, Wiley Eastern Limited.
2. Fraleigh J., 2013, *A first course in abstract algebra* (3rd Edition), Narosa Publishing House.
3. Bhattacharya P. B., Jain S. K. and Nagpal S. R., *Basic abstract algebra* (2nd Edition), Cambridge University Press.
4. Lal R., 2017, *Algebra Vol 1 & 2*, Springer, New York.
5. Jacobson N., 1984, *Basic Algebra*, Hind. Pub. Corp. New Delhi.

Course Code **MSM412**

Course Name **REAL ANALYSIS**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: To develop the concept of open ball in Euclidean space $\mathbb{R}^n$, covering of a set through open balls and some basic results of metric space, continuity and differentiability in $\mathbb{R}^n$ in addition to the concept of bounded variation and its properties. Moreover, to develop the understanding of uniform convergence and Riemann Stieltjes integral and its properties.

Learning Outcomes: Learner will be able to understand the concept of open ball in $\mathbb{R}^n$, and will solve the related problems. They will be able to solve the problem of differentiability in $\mathbb{R}^n$ and will apply the Taylor's theorem and inverse function theorem. They can solve problem of bounded variations, R-S integral, uniform convergence and will be able to apply its results.

Course Details:

Unit-I: Open ball and open sets, closed sets, adherent points, accumulation points, closure of sets, derived sets, Bolzano Weierstrass theorem. Cantor intersection theorem. Lindeloff covering theorem, Heine Borel theorem, Compactness in $\mathbb{R}^n$. open sets, closed sets, compact subsets of a metric space. **(15L)**

Unit-II: Monotonic functions and its properties, types of discontinuity functions of bounded variations and its properties, total variations. Continuity, partial derivatives, differentiability, derivatives of functions in an open set of $\mathbb{R}^n$ into $\mathbb{R}^n$ as a linear transformations, chain rule, Taylor's theorem, inverse function theorem, implicit function theorem and explicit function theorem, Jacobians. **(15L)**

Unit-III: Definition and existence of R-S integration, conditions of R-S integrability, properties of R-S integrals, integration and differentiation. Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Uniform convergence and R-S integration. **(15L)**

Recommended Readings:

1. Rudin W., 1976, Principles of Mathematical Analysis (3rd Ed.), McGraw Hill International Edition.
2. Apostol T. M., 1985, Mathematical Analysis by (2nd Ed.), Narosa Publishing House.
3. Natanson I. P., 1964, Theory of Functions of a Real Variable, Vol. 1, Frederick Pub. Co.
4. Royden H. L., Real Analysis, McMillan Publication Co. Inc. New York
5. Malik S. C. and Arora S., 2017, Mathematical Analysis, New Age Int. Ltd. Pub., New Delhi.

Course Code **MSM413**

Course Name **PROBABILITY AND MATHEMATICAL STATISTICS**

Credit, Mode **04, LTP:3+1+0**

Course Objective: The course is aimed at:

1. Providing students with a formal treatment of probability theory.
2. Equipping students with essential tools for statistical analyses at the graduate level.
3. Fostering understanding through real-world statistical applications.

Learning Outcomes: At the end of the course students should be able to:

1. Develop problem-solving techniques needed to accurately calculate probabilities.
2. Apply problem-solving techniques to solving real-world events.
3. Apply selected probability distributions to solve problems.
4. Present the analysis of derived statistics to all audiences.

Course Details:

Unit-I: Exploratory data analysis: summary statistics, box and whisker plots, histogram, P-P and Q-Q plots. Random Experiment and its sample space, probability as a set function on a collection of events, stating basic axioms, random variables, c.d.f., p.d.f., p.m.f., absolutely continuous and discrete distributions, Some common distributions (Negative Binomial, Pareto, lognormal, beta, etc). Transformations, moments, m.g.f., p.g.f., quantiles and symmetry. Random vectors, Joint distributions, copula, joint m.g.f. mixed moments, variance covariance matrix.

Unit-II: Independence, sums of independent random variables, conditional expectation and variances, compound distributions, prior and posterior distribution, best predictors. Sampling distributions of statistics from univariate normal random samples, chi-square, t and F distributions

Unit-III: Order statistics and the distribution of rth order statistic, joint distribution of rth and sth order statistics. Statement and application of central limit theorem for a sequence of independent and identically distributed random variables. Simulation techniques such as Monte Carlo, Resampling techniques.

Recommended Readings:

1. Ross and Sheldon M., 2003, *Introductory Statistics*.

2. Hogg R. V. and Craig, T. T., 1978, *Introduction to mathematical statistics (4th Ed.)*, Collier-McMillan.

3. Rohatgi V. K., 1988, *Introduction to probability theory and mathematical statistics*, Wiley Eastern.

4. Rao C. R., 1995, *Linear statistical inference and its Applications (2nd Ed.)*, Wiley Eastern.

5. Cramer H., 1946, *Mathematical methods of statistics*, Prinecton.

6. Gibbons J. D. and Chakraborti S., 1992, *Nonparametric statistical inference (3rd Ed.)*, Marcel Dekker, New York.

Course Code **MSM414**

Course Name **MATHEMATICAL PROGRAMMING**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: This course introduces the concepts of linear programming (LP) and non-linear programming (NLP) problems, emphasizing the underlying mathematical structures, geometrical ideas, algorithms and solutions of relevant practical problems. It discusses the theory of the simplex and dual simplex algorithm as solution techniques for LPP and the connection of a two person zero sum game with a primal-dual pair of linear programming problems. Further, it treats the non-linear programming problems by the method of Lagrange multipliers and provides the global max/min to a convex programming problem by Karush-Kuhn-Tucker conditions.

Learning Outcomes: Students will be ready to formulate a real-world problem as a mathematical programming model and to apply the appropriate method in order to find an optimal solution. They will understand the theoretical workings of the simplex/dual-simplex method for linear programming and perform iterations of it by hand. They will be able to solve specialized linear programming problems like the transportation, assignment problems and integer programming problems. In addition, they will learn how to obtain global max/min for a specialized non-linear programming problem by KKT conditions.

Course Details:

Unit-I: Linear Programming, Theoretical foundation of Simplex Method, Revised Simplex Method, Duality in linear programming problem, Primal-dual solution relationship, Duality theorems, Dual simplex method.**;** Post optimality analysis. **(15L)**

Unit-II: Integer Linear programming: Gomory's Cutting Plane Method, Branch & Bound Method. Multi-objective optimization theory. Goal Programming. Dynamic Programming, application of dynamic programming, Bellman's principle of optimality. **(15L)**

Unit-III: Nonlinear programming, Solution of nonlinear programming problem with equality constraints and with not all equality constraints, Kuhn-Tucker necessary and sufficient conditions for optimality of the objective function in NLPP. Quadratic programming, Wolfe's method and Beale's Method. **(15L)**

Recommended Readings:

1. Swarup K., Gupta P. K. and Mohan M., 2003, *Operations research*, S. Chand & Co.
2. Taha H., 1987, *Operations research*, Macmillan Co.
3. Hadley G., Linear programming, Oxford and IBH Publishing Co.
4. Gass S. I., 1965, *Linear programming*, Mcgraw Hill Book Co.

Course Code **MSM415**

Course Name **Ordinary Differential Equations**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: The aim of this course is to learn existence theory of scalar differential equations along with system of linear differential equations, quantitative information and qualitative methods which provide a good geometric understanding of ODE, Solution of boundary value problems: Sturm Liouville Problem and Green's function. The learner learns basics of stability of autonomous systems.

Learning Outcomes: After completion of the course, the learners will be able to understand the qualitative nature of ODE, solution of BVP, stability of criteria of autonomous systems. More precisely, students will learn how to do stability analysis of the systems which arise in different areas of science and engineering.

Course Details

Unit-I: Examples of non-uniqueness, non-existence, Importance of existence-uniqueness theory, Picard's iteration, Peano's Existence theory, Existence via Arzela Ascoli theorem, Existence and uniqueness of Higher order differential equations and Linear systems. **(15L)**

Unit-II: Two-point boundary-value problem, variation of parameters, Green's functions, Construction of Green's functions, Non homogeneous boundary conditions, Orthogonal sets of function, Sturm-Liouville boundary value problem, Eigenvalues and Eigen functions, The expansions of a function in a series of orthonormal Eigen functions. **(15L)**

Unit-III: Phase plane, Paths and Critical Points, Types of Critical Points, Stability of linear autonomous systems: Equilibrium points, Explicit phase portrait in 2D linear systems with constant coefficients, Critical Points and Paths of Nonlinear systems, Limit cycles, Stability by Lyapunov's Direct Method, Poincare Bendixon theory, Leinard's theorem. **(15 L)**

Recommended Readings:

1. Coddington E.R., Levinson N., 1984, *Theory of Ordinary Differential Equations*, McGraw Hill Education.
2. Simmons G.F., 2017 *Differential equations with applications and historical notes*, CRC Press
3. Ross S.L., 2004, *Differential Equations*, Wiley
4. Brauer F. and Nohel J.F., 1989, *Qualitative Theory of Differential Equations*, Dover Publications.
5. Nandkumaran A.K., Dutti P.S. and George R.K., 2017, *Ordinary Differential Equations: Principles and Applications*, Cambridge University Press.

Course Code **MSM421**

Course Name **LINEAR ALGEBRA**

Credit, Mode **04, LTP:3+1+0**

Course Overview: The core of linear algebra comprises the theory of linear equations in many variables, the theory of vector spaces and linear maps. The objective of this course is to introduce some advance material in Linear algebra.

Learning Outcomes: Students will deepen their understanding of Linear Algebra. They will be able to prove and apply the Primary Decomposition Theorem, and the criterion for diagonalisability. They will have a good knowledge of inner product spaces, and will be able to define and use the adjoint of a linear map on a finite-dimensional inner product space.

Course Details:

Unit-I: Matrix of Linear Transformation in different bases, Similar Matrices, Annihilating polynomials, Minimal polynomial of linear transformation, Eigen space, Diagonalizable linear transformation, Algebraic and Geometric Multiplicity, Simultaneous diagonalization, Tringularization.

Unit-II: Invariant subspace, Projection and idempotent linear transformation, Primary decomposition theorem, nilpotent matrices, Jordan decomposition Theorem, Canonical form for nilpotent matrix, computation of invariant factors, Rational and Jordan canonical form and its applications, Linear functional, dual and double dual, Annihilator of a subset, Dimension of annihilator of subspace, Transpose of linear transformation and its matrix.

Unit-III: Review of Inner Product Space, Inner product space isomorphism, Adjoint of a linear transformation, Self adjoint linear transformation, Image and kernel of adjoint, Matrix of adjoint, Symmetric and Skew-symmetric Bilinear Forms, Matrix of symmetric bilinear form in different bases, Diagonalization of symmetric bilinear forms, Quadratic forms, positive definite quadratic form, Rank and signature of quadratic form, Sylvester's Law of inertia.

Recommended Readings:

1. Hauffman K. and Kunze R., 1978, *Linear algebra*, PHI, New Delhi.
2. Lang S., 1987, *Linear Algebra*, Springer, New York.
3. Anton H. and Rorres C., 2010, *Elementary Linear Algebra*, John Wiley and Sons.
4. Halmos P. R., 2017, *Finite Dimensional Vector Spaces*, Dover Publications, New york.
5. Kumaresan S., 2000, *Linear Algebra: A Geometric Approach*,Narosa PPHI, New Delhi.

Course Code **MSM422**

Course Name **COMPLEX ANALYSIS**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: This course is aimed to provide an introduction to the theories for functions of a complex variable. Students will be equipped with the understanding of the fundamental concepts of complex variable theory.

Learning Outcomes: On completion of this unit successfully students will be able to evaluate integrals along a path, compute the Taylor and Laurent expansions of simple functions, determining the nature of the singularities and calculating residues, prove the Cauchy Residue Theorem and use it to evaluate integrals.

Course Details:

Unit-I: Functions of a complex Variable, Differentiability and analyticity, Cauchy Riemann Equations, Power series as an analytic function, properties of line integrals, Goursat Theorem, Cauchy theorem, consequence of simply connectivity, index of a closed curve. **(15L)**

Unit-II: Cauchy's integral formula, Morera's theorem, Liouville's theorem, Fundamental theorem of Algebra, Harmonic functions, Existence of Harmonic conjugate, Taylor's theorem, Zeros of Analytic functions, Laurent series, singularities, classification of singularities. **(15L)**

Unit-III: Maximum modulus theorem, Minimum modulus theorem, Hadamard three circle theorem, Schwarz's Lemma, Rouche's theorem, Calculation of residues, Residue theorem, Evaluation of integrals. **(15 L)**

Recommended Readings:

1. Ahlfors L.V., 1979, *Complex Analysis*, McGraw Hill Book Company.
2. Conway J.B., *Complex Analysis*, Narosa Publishing House.
3. Ponnusamy S., 2011, *Foundations of Complex Analysis*, Narosa Publication House.
4. Brown J.W, Churchill R.V., *Complex Variables and Applications*, McGraw Hill.

Course Code **MSM423**

Course Name **TOPOLOGY**

Credit, Mode **04, LTP:3+1+0**

Topological concepts play important role in the development of modern mathematics and it has large applications in theoretical physics.

Course Objectives:

1. Introduce the basic definitions and standard examples of topological spaces.
2. Define and illustrate a variety of topological properties such as like compactness, connectedness and separation axioms.
3. Explain the idea of topological equivalence and define homeomorphisms.

Learning Outcomes:

After completing the course, students will learn the following:

1. They understand well the concepts of homeomorphisms and how it preserves a variety of topological properties.
2. They know what we mean by connectedness, compactness, and hausdorf property and their general characteristics.
3. They can work with separation axioms and find their differences.
4. They can independently prove some old results of real line with the use of topological approaches.

Course details:

Unit-I: Topological spaces. Open sets, Closed sets. Interior points, Closure points. Limit points, Boundary points, exterior points of a set, Closure of a set, Derived set, Dense subsets. Basis, sub base, relative topology. **(15L)**

Unit-II: Continuous functions, open & closed functions, homeomorphism, Lindelof‟s, Separable spaces, Connected Spaces, locally connectedness, Connectedness on the real line, Components, Compact Spaces, one point compactification, compact sets, properties of Compactness and Connectedness under a continuous functions, Compactness and finite intersection property, Equivalence of Compactness. **(15L)**

Unit-III: Separation Axioms: T_0, T_1, and T_2 spaces, examples and basic properties, First and Second Countable Spaces, Regular, normal, T_3 & T_4 spaces, Tychnoff spaces, Urysohn's Lemma, Tietze Extension Theorem, finite product topological spaces and some properties. **(15L)**

Recommended reading:

1. Simmons G.F., 1963, *Topology and Modern Analysis*, McGraw Hill.
2. Pervin W.J., 1964, *Foundations of general topology*, Academic Press.
3. Munkers J.R., 1974, *Topology, A First Course*, Prentice Hall of India Pvt. Ltd.

Course Code **MSM424**

Course Name **PARTIAL DIFFERENTIAL EQUATIONS**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: The aim of this course is to learn theory of partial differential equations and solution methods. Nature of PDEs like parabolic, elliptic, hyperbolic.

Learning Outcomes: After completion of the course, the learners will be able to solve the PDEs independently. They can solve PDEs in higher dimension. Convert partial differential equations to canonical form.

Course Details:

Unit-I: Formation of PDEs: First order PDE in two and more independent variables, Derivation of PDE by elimination method of arbitrary constants and arbitrary functions. Lagrange's first order linear PDEs, Charpit's method for non-linear PDE of first order, Monge's method, Jacobi's method and Cauchy problem for first order PDEs. **(15L)**

Unit-II: PDEs of second order with variable coefficients: Classification of second order PDEs, Canonical form, Parabolic, Elliptic and Hyperbolic PDEs, Method of separation of variables for Laplace, Heat and Wave equations, Eigen values and Eigen functions of BVP, Orthogonality of Eigen function, , D' Almbert's solutions to wave equations. **(15L)**

Unit-III: General solution of higher order PDEs, Fundamental solution of Laplace Equation, Green's function for Laplace Equation, Wave equation, Diffusion Equation, Solution of BVP in spherical and cylindrical coordinates, Variational formulation of boundary value problem. **(15L**)

Recommended Readings:

1. Rao K.S. 2011, *Introduction to Partial Differential Equations*, 3rd Ed. PHI Learning.
2. Sneddon I.N. 2006, *Elements of Partial Differential Equations*, (unabridged republication) Dover Publications.
3. Jeffery A., 2002, *Applied Partial Differential Equation: An Introduction,* Academic Press.

Course Code **MBM531**

Course Name **FUNCTIONAL ANALYSIS**

Credit, Mode **04, LTP:3+1+0**

Functional analysis is one of the primary branches of mathematics mainly dealing with a variety of metrices and linear operators.

Course Objectives:

1. Define and illustrate several normed spaces;
2. Introduce linear operators and derive their properties.
3. Elaborate basic theorems like open and closed mapping theorem, implicit function theorem and spectral theorem.

Learning Outcomes:

After completing this course, students will learn the following:

1. They can work with different distance metrics and normed spaces.
2. They will understand the general properties of linear operators and their dependencies on the type of functional spaces;
3. They will be familiar with the natural embedding concepts and understand how it works in conjugate spaces.

Course Details:

Unit-I. Inner product spaces, Normed linear spaces, Banach spaces, Quotient norm spaces, continuous linear transformations, equivalent norms, the Hahn-Banach theorem and its consequences. Conjugate space and separability, second conjugate space, Weak *topology on the conjugate space. **(15L)**

Unit-II. The natural embedding of the normed linear space in its second conjugate space, The open apping Theorem, The closed graph theorem, The conjugate of an operator, The uniform boundedness principle, Definition and examples of a Hilbert space and simple properties, orthogonal sets and complements. **(15L)**

Unit -III. The projection theorem, separable Hilbert spaces. Bessel's inequality, the conjugate space, Riesz's theorem, The adjoint of an operator, self adjoint operators, Normal and unitary operators, Projections, Eigen values and eigenvectors of on operator on a Hilbert space, The spectral theorem on a finite dimensional Hilbert space. **(15L)**

Recommended Readings:

1. Simmons G.F. 1963, *Topology and modern analysis*, McGraw Hill.
2. Bachman G. and Narici, 1964, *Functional analysis*, Academic Press.
3. Taylor A.E., 1958, *Introduction to functional analysis*, John Wiley and sons.
4. Erwin Kreyszig E., 1978, *Introductory functional analysis with application*, Willey

Course Code **MSM532**

Course Name **NUMERICAL ANALYSIS**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: This course covers interpolation and iterative methods for linear, non-linear and polynomial. Further, it explains notion of numerical differentiation and numerical integration in detail. In addition, this course provides different methods to solve initial value problems and eigenvalue problems.

Learning Outcomes: After completion of this course, students will learn how to derive and apply numerical methods for various mathematical operations and problems, such as interpolation, differentiation, integration, the solution of linear and non-linear equations and the solution of initial value problems.

Course Details:

Unit-I: Polynomial equations-Descartes' rule of signs, Sturm sequence, root of a polynomial equation-iterative and direct methods. System of linear equations: error analysis for direct methods-Gauss elimination and Gauss-Jordan elimination method, convergence analysis for iterative methods- Gauss-Jacobi iterative method and Gauss- Seidel iterative method. **(15L)**

Unit-II: Hermite interpolation, piecewise and spline interpolation, cubic spline interpolation, numerical differentiation-methods based on interpolation and methods based on finite difference operators, methods based on undetermined coefficients, errors in numerical differentiation, numerical integration-methods based on interpolation and methods based on undetermined coefficients, composite integration methods, double integration. **(15L)**

Unit-III: Numerical solution of ordinary differential equations: initial value problems, existence and uniqueness of the solution of initial value problem, single step method-Taylor series, Picard's method, Euler's method, modified Euler method, Runge-Kutta method, multi-step method-Adam-Bashforth method, Adams-Moulton methods, stability analysis, predictor-corrector method, eigenvalue problem, power method, Jacobi method, Householder method. **(15L)**

Recommended Readings:

1. Atkinson K. E., 1989, *An Introduction to Numerical Analysis* (2nd Ed.), Wiley-India.
2. Buchaman J. I. and Turner P. R., 1992, *Numerical Methods and Analysis*, McGraw-Hill.
3. Jain M. K., Iyengar S. R. K. and Jain R. K., 2012, *Numerical Methods for Scientific and Engineering Computation* (6th Ed.), New Age International Publishers.

Course Code **MSM533**

Course Name **MEASURE THEORY & INTEGRATIONS**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: To develop the concept of countable, uncountable sets, Canter set, measurable sets, measurable functions, Lebesgue integral, and the Lebesgue L^p spaces. The concept of Lebesgue L^p Spaces, and some important related theorems are part of this course in order to sharpen the student's appetite for functional analysis.

Learning Outcomes: The students will understand the need of development of modern theory of measure and integrations. The student will be able to understand that the Lebesgue integration is more general theory than Riemann integration theory and will be aware with some examples of functions which are not integrable in sense of Riemann theory of integration but they are integrable in sense of Lebesgue integration.

Course Details:

Unit-I: Countable and uncountable sets, cardinality and cardinal arithmetic, Schroder–Bernstein theorem, the Cantor's ternary set, Semi-algebras, Algebras, Monotone class, Measure and outer measures, Carathe dory extension process of extending a measure on a semi-algebra to generated algebras, Borel sets. **(15L)**

Unit-II: Lebesgue outer measure and Lebesgue measure on R, Translation invariance of Lebesgue measure, Existence of a non-measurable set, Characterizations of Lebesgue measurable sets, The Cantor-Lebesgue function, Measurable functions on a measure space and their properties, Borel and Lebesgue measurable functions, Simple functions and their integrals, Littlewood's three principle (statement only). **(15L)**

Unit-III: Lebesgue integral on R and its properties, Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem, L^p-spaces, Holder-Minkowski inequalities, parseval's identity, Riesz Fisher's theorem. **(15L)**

Recommended Readings:

1. Royden H. L. and Fitzpatrick P. M., 2010, *Real Analysis (4th Ed.)*, PHI.
2. Halmos P. R., 1994, *Measure theory*, Springer.
3. Hewit E. and Stromberg K., 1975, *Real and abstract analysis*, Springer.
4. Parthasarathy K. R., 2005, *Introduction to probability and measure*, Hindustan Book Agency.
5. Rana I. K., 2005, *An introduction to measure and integration (2nd Ed.)*, Narosa Publishing House.

Course Code **MSM541**

Course Name **MATHEMATICAL MODELING**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: The aim of this course is to learn different type of mathematical models and their nature.

Learning Outcomes: After completion of the course, the learners will be able to make the mathematical model of different situations in population dynamics, ecology, epidemics etc. They can solve these models and predict the different type of analysis.

Course Details:

Unit-I: Introduction to modeling. Definition of System, classification of systems, classification and limitations of mathematical models, Methodology of model building, Modeling through ordinary differential equation: linear growth and decay models, non-linear growth and decay models, Compartment models. **(15L)**

Unit-II: Checking model validity, verification of models, Stability analysis, Basic model relevant to population dynamics, Epidemics modeling, Ecology, Environment Biology through ordinary differential equation, Partial differential equation. **(15L)**

Unit-III: Basic theory of linear difference equations with constant coefficients, Mathematical modeling through difference equations in population dynamics, genetics, Markov chains model, Gambler's ruin model, Stochastic models, Monte Carlo methods. **(15L)**

Recommended Readings:

1. Murthy D. N. P., Page N. W. and Rodin E. Y., 1990, Mathematical Modelling: A tool for problem solving in Engineering, Physics, Biological and Social Sciences, Pergamon Press.
2. Kapoor J. N., 2008, *Mathematical modelling*, New Age Int. Pub.
3. Law A. M. and Kelton W. D., 1991, *Simulation modeling and analysis*, McGraw-Hill.

Course Code **MSM542**

Course Name **DYNAMICS OF RIGID BODY**

Credit, Mode **04, LTP:3+1+0**

Course Objectives: To develop the understanding of moments of inertia and its applications in the dynamics of a rigid body rotating about a fixed point, concept of geometrical equations and Lagrange's equations of motion of a rigid body, principles of Hamiltonian, Liouville's Theorem and introduction to Lagrange and Poisson brackets and its applications.

Learning Outcomes: Learner will be able to write equations of motion through Euler's dynamical equations, Lagrange's mechanics and Hamiltonian mechanics and will be able to solve related problems. They will know about the Liouville's Theorem and they will evaluate Lagrange and Poisson brackets and will be able to find the canonical transformations.

Course Details:

Unit-I: Moments and products of inertia, moment of inertia of a body about a line through the origin, Momental ellipsoid, rotation of coordinate axes, principal axes and principal moments. K.E. of rigid body rotating about a fixed points, angular momentum of a rigid body, Eulerian angle, angular velocity, K.E. and angular momentum in terms of Eulerian angle. Euler's equations of motion for a rigid body, rotating about a fixed point, torque free motion of a symmetrical rigid body (rotational motion of Earth). **(15L)**

Unit-II: Classification of dynamical systems, Generalized coordinates systems, geometrical equations, Lagrange's equation for a simple system using D'Alembert principle, Deduction of equation of energy, deduction of Euler's dynamical equations from Lagrange's equations, Hamilton's equations, Ignorable coordinates, Routhian Function. **(15L)**

Unit-III: Hamiltonian principle for a conservative system, principle of least action, Hamilton-Jacobi equation, Phase space and Liouville's Theorem, Canonical transformation and its properties, Lagrange Brackets, and Poisson brackets, Poisson-Jacobi identity. **(15L)**

Recommended Readings:

1. Milne E. A., 1965, Vectorial Mechanics, Methuen & Co. Ltd. London.
2. Ramsey A.S., 1985, Dynamics (Part II), CBS Publishers & Distributors, Delhi.
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