M. Sc., Mathematics Program and Course Outcome.

Program Specific Outcomes

After successful completion of program, students will be able to:

1. Understanding of the fundamental laws/axioms/postulates in pure mathematics and capability of developing new mathematical ideas.
2. Understanding of the concepts and theories of mathematics and their application in the real world.
3. Acquire knowledge in recent developments in various branches of Mathematics and thus pursue research.
4. Prepare and motivate students for research studies in advanced mathematics and related applications in different field like scientific, engineering and technology domains.
5. Provide advanced knowledge in pure mathematics, it empowering the students to pursue higher degrees at reputed national/ international universities /research institutions like IISc, TIFR, CMI and NBHM.
6. Good understanding of Differential Geometry/Riemannian Geometry/Finsler Geometry, which have very good applications in Einstein Theory of Relativity and cosmology.
7. Strong foundation in Fluid Mechanics/MHD it provides an applications in Mechanical Engineering.
8. Real word problem solving skills, creative thinking, assist to new project works and preparing the students for competitive examinations, in particular JRF/NET/GATE etc.

I Semester

Paper Title: MSM 1.1: ALGEBRA

Student Learning Course Outcomes

After successful completion of this course, students will be able to: -

To introduce the concepts and to develop elementary working knowledge of algebra. This course is a foundation for next course in Algebra. At the end of the course students will have the knowledge and skills to understand in fundamental concepts of:

- Groups and Structure of Groups
- Permutation Groups
- Rings and Euclidean Ring
- Fields and Extension Fields
- Splitting Fields

Paper Title: MSM 1.2: REAL ANALYSIS-I

Course Specific Outcome: At the end of the course students will have the knowledge and skills

- To study the real number system and their properties in detail.
- To develop skills to work with sequences in arbitrary metric spaces.
- To develop skills to work with series of real numbers.
- To study the concepts of continuous functions and differentiable functions.

Paper Title: MSM 1.3: COMPLEX ANALYSIS-I

Course Specific Outcome: At the end of the course students will possess a strong foundation in complex number theory, analytic functions, power series, and complex integration demonstrating both knowledge and practical skills in these areas and :

- Understand the basics of complex numbers, covering arithmetic operations, square roots, and geometric interpretations.
- Demonstrate expertise in limits, continuity, and differentiability for complex-valued functions.
- Acquire proficiency in solving power series, encompassing concepts of uniform convergence and radius of convergence.
- Develop skills in complex integration, including line integrals, conformal mappings, and applications like Cauchy's theorems and the Cauchy integral formula.

Paper Title: MSM 1.4: ORDINARY DIFFERENTIAL EQUATIONS

Course Specific Outcome: Upon completion of the course, students will have achieved the following specific outcomes:

- Mastery in Solving First-Order Differential Equations
- Advanced Understanding of Higher Order Equations:
- Expertise in Oscillations and Power Series Solutions:
- Proficiency in Systems and Successive Approximations:

Paper Title: MSM 1.5: DISCRETE MATHEMATICS AND C-PROGRAMMING

Course Specific Outcome: After study the course, students will have achieved the following specific outcomes:

- Develop a robust foundation in lattice theory, Boolean algebra, and number theory, honing skills in comprehending ordered sets, Boolean expressions, and number properties.
- Gain proficiency in 'C' programming language, covering development, features, data types.
- Understand essential concepts in number theory,
- Attain proficiency in programming control structures and functions.

Paper Title: MSM 1.6: LAB: C-PROGRAMS

Course Specific Outcome: Upon completion of the course, students will have achieved the following specific outcomes:

- Develop the ability to write and execute programs for algebraic operations.
- Acquire skills in designing programs for converting binary to decimal and vice versa.
- Demonstrate competence in writing programs for mathematical computations.
- Develop proficiency in array manipulation.

II Semester

Paper Title: MSM 2.1: LINEAR ALGEBRA

Course Specific Outcome: At the end of the course students will have the knowledge and skills.

- To acquaint knowledge in the theory of vector spaces
- Exploration of Inner Product Spaces
- Explore the matrix representation of linear transformations,
- Explore concepts of Hermitian adjoints

Paper Title: MSM 2.2: REAL ANALYSIS-II

Course Specific Outcome: At the end of the course Students will have the knowledge and skills to explain:

- The Riemann-Stieltjes, Integral, Rectifiable curves, Improper Integrals.
- Sequences and Series of Functions, Uniform convergence, and continuity.
- Integration, differentiation, Equicontinuous families of functions.
- The Stone-Weierstrass theorem.
- Functions of several variables: Differentiation, The contraction principle, The inverse function
- theorem, The implicit function theorem.

Paper Title: MSM 2.3: COMPLEX ANALYSIS-II

Course Specific Outcome: At the end of the course students will have the knowledge and skills on:

- Understand singularities, Taylor's theorem, and meromorphic functions, including applications like Weierstrass theorem.
- Explore the calculus of residues, the residue theorem, and techniques for evaluating specific integrals.

- Comprehend harmonic functions, Laplace's equation, mean value property, and principles governing their behavior.
- Learn about partial fractions, infinite products, the gamma function, Stirling's formula, and properties of entire functions.

Paper Title: MSM 2.4: PARTIAL DIFFERENTIAL EQUATIONS

Course Specific Outcome: At the end of the course Students will have the knowledge and skills to understand, explain in depth and apply in various situations the techniques to

- Master the construction and solutions of first-order partial differential equations and delve into second-order equations with variable coefficients and canonical forms.
- Solve parabolic equations using separation of variables, eigenfunction expansion, Laplace and Fourier transform methods, Duhamel's Principle, and apply them to higher-dimensional spaces.
- Explore hyperbolic equations, employing characteristics method, separation of variables, eigenfunctions expansion, Laplace and Fourier transform methods, Duhamel's Principle, and solutions in higher dimensions.
- Understand elliptic equations, solving them through separation of variables, eigenfunctions expansion, Fourier transform method, and similarity transformation method, with applications in cylindrical and spherical coordinate systems.

Paper Title: MSM 2.5: DIFFERENTIAL GEOMETRY

Course Specific Outcome: At the end of the course students will have the knowledge and skills.

- Explore the basics, including parametrized curves, level curves, curvature, and smooth surfaces.
- Understand tangent vectors, vector fields, and directional derivatives in Euclidean space.
- Explore 1-forms, differential forms, and mappings on Euclidean spaces.
- Delve into calculus on surfaces, Frenet formulas, and curvature of unit-speed curves.
- Understand arbitrary speed curves, covariant derivatives, and connection forms of a frame field.
- Explore calculus on surfaces, tangent vectors, tangent planes, and vector fields on surfaces.
- Understand first and second fundamental forms, length of curves on surfaces, and curvature of curves on surfaces.
- Define shape operators, normal curvature, Gaussian curvature, and explore special curves in surfaces.

Paper Title: MSM 2.6: LAB: MATLAB PROGRAMMING

Course Specific Outcome: Students will have the knowledge and skills to implement the programmes listed below in the Scilab programming language. They can be expected to apply these programming skills of computation in science and Engineering.

- Develop a program to find solutions to a system of linear equations using matrix inversion.
- Implement a program to find solutions to a system of linear equations using Cramer's rule.
- Design a program to find the area of geometric figures (circle, triangle, rectangle, square) using switch statements.
- Develop a program to find the approximate solution of a differential equation with an initial condition using Picard's method of successive approximation.
- Implement a program to find the numerical solution of a differential equation with an initial condition using Euler's modified method.
- Create a program to plot a neat labeled graph of sine and cosine functions on the same graph.
- Implement a program to plot a neat labeled graph of functions.
- $f(x) = x^2, g(x) = x^3 - 1, and\ h(x) = e^x$ on the same graph.
- Develop a program to obtain the graph of plane curves cycloid and astroid in separate figures on a single run.
- Design a program to obtain a neat labeled graph of surfaces elliptic paraboloid and hyperbolic paraboloid in separate figures on a single run.

Paper Title: MSM 2.7: Elective: BASIC MATHEMATICAL MODELLING

Course Specific Outcome: At the end of the course students will have the knowledge and skills.

- Understand the concept of mathematical modeling, including its definition, classification, characteristics, and limitations.
- Explore the development of model equations, focusing on special types of differential equations, the origin of ODEs and PDEs, and methods for solving nonlinear ODEs.
- Gain insights into techniques for solving differential equations.
- Learn about function fitting, model estimation, least squares methods.

III Semester

Paper Title: MSM 3.1: Measure Theory and Integration

Course Specific Outcome: At the end of the course students will have the knowledge and skills to-

- Gain a comprehensive understanding of Lebesgue measure, including outer measure, measurable sets, translation invariance, algebra of measurable sets, Borel sets, and properties like countable subadditivity.

- Analysis of Measurable Functions: - Analyze measurable functions, covering characteristic functions, constant functions, continuous functions, and properties like Littlewood's three principles.
- Master techniques related to Lebesgue integral, including the Riemann integral, integral of simple functions, and the bounded convergence theorem.
- Explore principles of integration and differentiation, including differentiation of monotone functions, Lebesgue differentiation theorem, functions of bounded variation, and properties like Jordan's theorem.

Paper Title: MSM 3.2: TOPOLOGY-I

Course Specific Outcome: At the end of the course Students will have the knowledge and skills. To explain demonstrate accurate and efficient use of the following advanced topics in various situations –

- Review fundamental concepts in set theory, logic, and well-ordered sets.
- Explore basic topological spaces, continuity principles, and convergence theorems.
- Understand the product topology, weak topology, and the concept of quotient space.
- Study properties of connected and compact spaces, including path-connectedness, components, and various compactness theorems.

Paper Title: NUMERICAL ANALYSIS-I

Course Specific Outcome: At the end of the course students will have the knowledge and skills

- Obtain the solutions of Transcendental and Polynomial Equations.
- Solve by Direct methods and Iteration methods for solving system of equations.
- Understand eigenvalues and eigenvectors computation.
- Apply Hermite Interpolation
- Solve problems using interpolation.
- Solve Ordinary Differential Equations using Numerical methods.

Paper Title: MSM-3.4: RIEMANNIAN GEOMETRY

Course Specific Outcome: At the end of the course students will have the knowledge and skills

- Understand preliminary concepts on Euclidean space, topological manifolds
- Understand about the Differentiable Manifolds and examples
- Study Riemannian metrics, Riemannian manifolds, local representations of metrics, connections
- Delve into curvature, Gauss and Codazzi-Mainardi equations, tangential and normal curvature equations, tensor concepts,
- Explore hypersurfaces, Gauss map, Weingarten map, fundamental theorems of hypersurface theory, and Gauss-Bonnet theorem.

Paper Title: MSM 3.5: FLUID MECHANICS

Course Specific Outcome: At the end of the course Students will have the knowledge and skills to understand, explain in depth and apply in various situations the concepts –

- Explore pressure in fluids at rest and in motion, Euler's equation, Barotropic flows, Bernoulli's equations, vortex motion, circulation, Kelvin's circulation theorem.
- Study two-dimensional flows, stream function, complex potential, line sources, line sinks, line doublets, and line vortices., explore Milne Thomson circle theorem.
- fluid flow measurement
- the losses in a flow system, flow through pipes, boundary layer flow and flow past immersed bodies.

Paper Title: MSM 3.6: LAB: NUMERICAL METHODS

Course Specific Outcome: At the end of the course Students will have the knowledge and skills to write and execute –

- Develop a C-program to handle polynomial coefficients, print the polynomial, and evaluate it at a specified value.
- Implement C-programs for fundamental matrix operations, including finding the transpose, product, trace, and norm of matrices.
- Write C-programs to determine whether a matrix is symmetric or skew-symmetric, showcasing applications in linear algebra.
- Create programs for solving systems of linear equations using Gauss Elimination, Gauss Jordan, Jacobi Iterative, and Gauss Seidal methods.
- Find the root by different methods.

Paper Title: MSM 3.7: Elective: STATISTICAL TECHNIQUES

Course Specific Outcome: At the end of the course Students will have to understand, explain in depth and apply in various situations the concepts like–

- Understand the fundamentals of probability,
- Master interpolation concepts using finite difference operators, Newton's forward and backward formulas
- Learn finite difference formulas for numerical differentiation and numerical integration methods like Trapezoidal and Simpson's rules.
- Solve systems of linear algebraic equations using both direct methods (Gauss elimination, LU decomposition) and iterative methods (Jacobi, Gauss-Seidel, SOR).

IV Semester

Paper Title: MSM 4.1: FUNCTIONAL ANALYSIS

Course Specific Outcome: At the end of the course Students will have the knowledge and skills to understand–

- the concept of normed linear spaces and Banach spaces.
- Explore isometric isomorphism, operators, equivalent norms, and Reisz lemma.
- Study functional conjugate spaces, Hahn-Banach theorem, and related consequences.
- Grasp the fundamentals of Hilbert spaces, inner product, orthogonal complements.
- Understand Reisz representation theorem, adjoint operators, self-adjoint, normal, and unitary operators, as well as projections.

Paper Title: MSM 4.2: TOPOLOGY-II

Course Specific Outcome: At the end of the course Students will have the knowledge and skills to understand -

- Explore countability, separation axioms, and other properties.
- Study Urysohn's Lemma, Tietze's extension theorem, and Urysohn's metrization theorem,
- Understand Tychonoff's theorem and its implications, as well as the Stone-Čech compactification.
- Explore paracompactness, Nagata-Smirnov metrization theorem.
- Study covering spaces, including the fundamental group of circles.

Paper Title: MSM 4.3: NUMERICAL ANALYSIS-II

Course Specific Outcome: At the end of the course students will have the knowledge and skills to:

- Explore numerical differentiation techniques.
- Delve into methods for solving initial value problems in ordinary differential equations (ODEs), including Euler's method and Runge-Kutta methods.
- Explore shooting methods and the midpoint method.
- Study finite difference approximations to derivatives and numerical solutions for Laplace, heat, and wave equations in partial differential equations

Paper Title: MSM 4.4: TENSOR ANALYSIS AND RELATIVITY

Course Specific Outcome: At the end of the course students will have the knowledge and skills to ;

- Understand the concept of tensors and their operations, Einstein summation convention, coordinate transformations, and properties of vectors and tensors.
- Explore contravariant and covariant tensors, tensors of various orders, and operations like addition and multiplication.
- Examine Riemannian metrics, Christoffel symbols, and covariant differentiation for vectors and tensors. Einstein tensor, Ricci tensor
- Gain insights into inertial and non-inertial frames, the special theory of relativity, and Minkowski space.

- Explore gravity as space-time curvature, geodesics, and the essentials of space-time in a relativistic framework.
- Understand the energy-momentum tensor and the heuristic approach to derive Einstein's field equations.
- Explore solutions, including the Schwarzschild, de Sitter, Schwarzschild-de Sitter, and Reissner-Nordstrom solutions:

Paper Title: MSM 4.5A: FINSLER GEOMETRY

Course Specific Outcome: At the end of the course students will have the knowledge and develop the skills on-

- Explore inner product, contraction, and the concepts of symmetric and antisymmetric tensors through examples.
- Understand the Christoffel symbols and their significance in connection with Riemannian metrics.
- Understand the Finsler space, examine the Hamiltonian function, and discuss generalized Christoffel symbols and geodesics.
- Explore Cartan's and Berwald's covariant differentiation, along with parameters and deductions.
- Generalize Bianchi identities, explore spaces of scalar and constant curvature, and delve into recurrent and symmetric spaces.

Paper Title: MSM 4.6: LAB: NUMERICAL METHODS

Course Specific Outcome: At the end of the course students will have the knowledge and skills-

- Develop a C-program to efficiently evaluate a given integral using the Trapezoidal rule
- Develop a C-program to find the solution of an initial value problem using the Runge-Kutta II, III, IV order Method.
- Develop a C-program to find the value of a function using Lagrange Interpolation Method.
- Develop a C-program for the numerical solution of the Heat equation using Schmidt method.
- Implement a C-program for the numerical solution of the wave equation using Finite difference method.

Paper Title: MSM 4.5: PROJECT WORK

Course Specific Outcome: general outcomes that can result from engaging in project work:

- Gain the ability to apply theoretical knowledge and academic skills to real-world problems.
- Develop critical thinking skills by identifying, analyzing, and solving complex problems, fostering a capacity for independent thought and decision-making.
- Enhance communication skills through project documentation, presentations, and possibly collaboration.

- Acquire project management skills, including planning, organization, time management, and the ability to meet deadlines.
