

PROGRAM OUTCOMES AND COURSE OUTCOMES FOR COURSES OFFERED BY DEPARTMENT OF MATHEMATICS

B.Sc. (Hons.) Mathematics

Programme Objectives: Students who choose B.Sc. (Hons.) Mathematics Programme, develop the ability to think critically, logically and analytically and hence use mathematical reasoning in everyday life. Pursuing a degree in mathematics will introduce the students to a number of interesting and useful ideas in preparations for a number of mathematics careers in education, research, government sector, business sector and industry. The programme covers the full range of mathematics, from classical Calculus to Modern Cryptography, Information Theory, and Network Security. The course lays a structured foundation of Calculus, Real & Complex analysis, Abstract Algebra, Differential Equations (including Mathematical Modeling), Number Theory, Graph Theory, and C++ Programming exclusively for Mathematics. An exceptionally broad range of topics covering Pure & Applied Mathematics: Linear Algebra, Metric Spaces, Statistics, Linear Programming, Numerical Analysis, Mathematical Finance, Coding Theory, Mechanics and Biomathematics cater to varied interests and ambitions. Also hand on sessions in Computer Lab using various Computer Algebra Systems (CAS) softwares such as Mathematica, MATLAB, Maxima, R to have a deep conceptual understanding of the above tools are carried out to widen the horizon of students' self-experience. To broaden the interest for interconnectedness between formerly separate disciplines one can choose from the list of Generic electives for example one can opt for economics as one of the GE papers. Skill enhancement Courses enable the student acquire the skill relevant to the main subject. Choices from Discipline Specific Electives provides the student with liberty of exploring his interests within the main subject. Of key importance is the theme of integrating mathematical and professional skills. The wellstructured programme empowers the student with the skills and knowledge leading to enhanced career opportunities in industry, commerce, education, finance and research.

Programme Learning Outcomes: The completion of the B.Sc. (Hons.) Mathematics Programme will enable a student to:

- i) Communicate mathematics effectively by written, computational and graphic means.
- ii) Create mathematical ideas from basic axioms.
- iii) Gauge the hypothesis, theories, techniques and proofs provisionally.
- iv) Utilize mathematics to solve theoretical and applied problems by critical understanding, analysis and synthesis.
- v) Identify applications of mathematics in other disciplines and in the real-world, leading to enhancement of career prospects in a plethora of fields and research.

Semester-I

- **Paper Name: Calculus (UPC: 32351101)**

Course Objectives: The primary objective of this course is to introduce the basic tools of calculus and geometric properties of different conic sections which are helpful in understanding their applications in planetary motion, design of telescope and to the real-world problems. Also, to carry out the hand on sessions in computer lab to have a deep conceptual understanding of the above tools to widen the horizon of students' self-experience.

Course Learning Outcomes: This course will enable the students to:

- i) Sketch curves in a plane using its mathematical properties in the different coordinate systems of reference.
- ii) Apply derivatives in Optimization, Social sciences, Physics and Life sciences etc.
- iii) Compute area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.

- **Paper Name: Algebra (UPC: 32351102)**

Course Objectives: The primary objective of this course is to introduce the basic tools of theory of equations, complex numbers, number theory and matrices to understand their linkage to the real-world problems. Perform matrix algebra with applications to Computer Graphics.

Course Learning Outcomes: This course will enable the students to:

- i) Employ De Moivre's theorem in a number of applications to solve numerical problems.
- ii) Apply Euclid's algorithm and backwards substitution to find greatest common divisor.
- iii) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.
- iv) Find eigenvalues and corresponding eigenvectors for a square matrix.

Semester-II

- **Paper Name: Real Analysis (UPC: 32351201)**

Course Objectives: The course will develop a deep and rigorous understanding of real line and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications in real life scenario.

Course Learning Outcomes: This course will enable the students to:

- i) Understand many properties of the real line and learn to define sequence in terms of functions from to a subset of Real Numbers.
- ii) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence. iii) Apply the ratio, root, and alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

- **Paper Name: Differential Equations (UPC: 32351202)**

Course Objectives: The main objectives of this course are to introduce the students to the exciting world of Differential Equations, Mathematical Modeling and their applications.

Course Learning Outcomes: The course will enable the students to:

- i) Formulate Differential Equations for various Mathematical models.
- ii) Solve first order non-linear differential equation and linear differential equations of higher order using various techniques.
- iii) Apply these techniques to solve and analyze various mathematical models.

Semester- III

- **Paper Name: Theory of Real Functions (UPC: 32351301)**

Course Objectives: It is a basic course on the study of real valued functions that would develop an analytical ability to have a more matured perspective of the key concepts of calculus, namely, limits, continuity, differentiability and their applications.

Course Learning Outcomes: This course will enable the students to learn:

- To have a rigorous understanding of the concept of limit of a function.
- The geometrical properties of continuous functions on closed and bounded intervals.
- The applications of mean value theorem and Taylor's theorem.

- **Paper Name: Group Theory-I (UPC: 32351302)**

Course Objectives: The objective of the course is to introduce the fundamental theory of groups and their homomorphisms. Symmetric groups and group of symmetries are also studied in detail. Fermat's Little theorem as a consequence of the Lagrange's theorem on finite groups.

Course Learning Outcomes: The course will enable the students to:

- Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc;
- Link the fundamental concepts of Groups and symmetrical figures;
- Analyze the subgroups of cyclic groups;
- Explain the significance of the notion of cosets, normal subgroups, and factor groups.

- **Paper Name: Multivariate Calculus (UPC: 32351303)**

Course Objectives: To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables. Also, the emphasis will be on the use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding.

Course Learning Outcomes: This course will enable the students to learn:

- The conceptual variations when advancing in calculus from one variable to multivariable discussions.
- Inter-relationship amongst the line integral, double and triple integral formulations.
- Applications of multi variable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

- **Paper Name: SEC-1- LaTeX and HTML (UPC: 32353301)**

Course Objectives: The purpose of this course is to acquaint students with the latest typesetting skills, which shall enable them to prepare high quality typesetting, beamer presentation and webpages.

Course Learning Outcomes: After studying this course the student will be able to:

- Typeset mathematical formulas, use nested list, tabular & array environments.
- Create or import graphics.

- iii) Use beamer to create presentation and HTML to create a web page.

Semester-IV

- **Paper Name: Partial Differential Equations (UPC: 32351401)**

Course Objectives: The main objectives of this course are to teach students to form and solve partial differential equations and use them in solving some physical problems.

Course Learning Outcomes: The course will enable the students to:

- i) Formulate, classify and transform partial differential equations into canonical form.
- ii) Solve linear and non-linear partial differential equations using various methods; and apply these methods in solving some physical problems.

- **Paper Name: Riemann Integration & Series of Functions (UPC: 32351402)**

Course Objectives: To understand the integration of bounded functions on a closed and bounded interval and its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration. The sequence and series of real valued functions, and an important class of series of functions (i.e., power series).

Course Learning Outcomes: The course will enable the students to learn about:

- i) Some of the families and properties of Riemann integrable functions, and the applications of the fundamental theorems of integration.
- ii) Beta and Gamma functions and their properties.
- iii) The valid situations for the inter-changeability of differentiability and integrability with infinite sum, and approximation of transcendental functions in terms of power series.

- **Paper Name: Ring Theory & Linear Algebra-I (UPC: 32351403)**

Course Objectives: The objective of this course is to introduce the fundamental theory of two objects, namely - rings and vector spaces, and their corresponding homomorphisms.

Course Learning Outcomes: The course will enable the students to learn about:

- i) The fundamental concept of Rings, Fields, subrings, integral domains and the corresponding morphisms.
- ii) The concept of linear independence of vectors over a field, the idea of a finite dimensional vector space, basis of a vector space and the dimension of a vector space.
- iii) Basic concepts of linear transformations, the Rank-Nullity Theorem, matrix of a linear transformation, algebra of transformations and the change of basis.

- **Paper Name: SEC-2-Computer Algebra Systems and Related Software (UPC: 32353401)**

Course Objectives: This course aims at familiarizing students with the usage of computer algebra systems (/Mathematica/MATLAB/Maxima/Maple) and the statistical software R. The basic emphasis is on plotting and working with matrices using CAS. Data entry and summary commands will be studied in R. Graphical representation of data shall also be explored.

Course Learning Outcomes: This course will enable the students to:

- i) Use CAS as a calculator, for plotting functions, animations and various applications of matrices.
- ii) Understand the use of the software R for entry, summary calculation, pictorial representation of data and exploring relationship between data
- iii) Analyze, test, and interpret technical arguments on the basis of geometry.

Semester V

- **Paper Name: Metric Spaces (UPC: 32351501)**

Course Objectives: The course aims at providing the basic knowledge pertaining to metric spaces such as open and closed balls, neighbourhood, interior, closure, subspace, continuity, compactness, connectedness etc.

Course Learning Outcomes: The course will enable the students to:

- i) Understand the basic concepts of metric spaces;
- ii) Correlate these concepts to their counter parts in real analysis;
- iii) Appreciate the abstractness of the concepts such as open balls, closed balls, compactness, connectedness etc. beyond their geometrical imaginations.

- **Paper Name: Group Theory-II (UPC: 32351502)**

Course Objectives: The course will develop an in-depth understanding of one of the most important branch of the abstract algebra with applications to practical real-world problems. Classification of all finite Abelian groups (up to isomorphism) can be done.

Course Learning Outcomes: The course shall enable students to learn about:

- i) Automorphisms for constructing new groups from the given group.
- ii) External direct product $\mathbb{Z} \times \mathbb{Z} \times \mathbb{Z}$ applies to data security and electric circuits.
- iii) Group actions, Sylow theorems and their applications to check nonsimplicity.

- **Paper Name: DSE1- Numerical Methods (UPC: 32357501)**

Course Objectives: To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and ordinary differential equations. Also, the use of Computer Algebra System (CAS) by which the numerical problems can be solved both numerically and analytically, and to enhance the problem solving skills.

Course Learning Outcomes: The course will enable the students to learn the following:

- i) Some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
- ii) Interpolation techniques to compute the values for a tabulated function at points not in the table.
- iii) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

- **Paper Name: DSE2-Discrete Mathematics (UPC: 32357505)**

Course Objectives: This course aims at introducing the concepts of lattices, Boolean algebras, switching circuits and graph theory. The course discusses some important applications of Boolean algebra and graph theory in real life situations through switching circuits and shortest path algorithms.

Course Learning outcomes: After the course, the student will be able to understand the concepts of:

- i) Lattices and their types;
- ii) Boolean algebra, switching circuits and their applications;
- iii) Graphs, their types and its applications in study of shortest path algorithms.

Semester VI

- **Paper Name: Complex Analysis (UPC: 32351601)**

Course Objectives: This course aims to introduce the basic ideas of analysis for complex functions in complex variables with visualization through relevant practicals. Particular emphasis has been laid on Cauchy's theorems, series expansions and calculation of residues.

Course Learning Outcomes: The completion of the course will enable the students to:

- i) Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equations.
- ii) Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.
- iii) Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues and apply Cauchy Residue theorem to evaluate integrals.

- **Paper Name: Ring Theory and Linear Algebra-II (UPC: 32351602)**

Course Objectives: This course introduces the basic concepts of ring of polynomials and irreducibility tests for polynomials over ring of integers, used in finite fields with applications in Cryptography. This course emphasizes the application of techniques using the adjoint of a linear operator and their properties to least squares approximation and minimal solutions to systems of linear equations.

Courses Learning Outcomes: On completion of this course, the student will be able to:

- i) Appreciate the significance of unique factorization in rings and integral domains.
- ii) Compute with the characteristic polynomial, eigenvalues, eigenvectors, and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result.
- iii) Compute inner products and determine orthogonality on vector spaces, including Gram-Schmidt orthogonalization to obtain orthonormal basis.

- **Paper Name: DSE3- Probability Theory and Statistics (UPC: 32357607)**

Course Objectives: To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness. The course intends to render the students to several examples and exercises that blend their everyday experiences with their scientific interests.

Course Learning Outcomes: This course will enable the students to learn:

- i) Distributions to study the joint behaviour of two random variables.
- ii) To establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.
- iii) Central limit theorem, which helps to understand the remarkable fact that: the empirical frequencies of so many natural populations, exhibit a bell shaped curve.

- **Paper Name: DSE4- Linear Programming and Theory of Games (UPC: 32357611)**

Course Objectives: This course develops the ideas underlying the Simplex Method for Linear Programming Problem, as an important branch of Operations Research. The course covers Linear Programming with applications to Transportation, Assignment and Game Problem. Such problems arise in manufacturing resource planning and financial sectors.

Course Learning Outcomes: This course will enable the students to learn:

- i) Analyze and solve linear programming models of real life situations.
- ii) The graphical solution of LPP with only two variables, and illustrate the concept of convex set and extreme points. The theory of the simplex method is developed.
- iii) The relationships between the primal and dual problems and their solutions with applications to transportation, assignment and two-person zero-sum game problem.

Generic Elective Courses Offered by Department of Mathematics to B.Sc. (H) / B. A. (H) / B. Com (H) (Other than B.Sc. (H) Mathematics)

● **GE1: Calculus (UPC: 32355101)**

Course Objectives: The main aim of this course is to introduce the concept of differentiation of functions, points of inflection, curve sketching etc. Concepts of functions of several variables, their partial derivatives and saddle points is also discussed.

Course Learning Outcomes: This course will enable the students to:

- i) Visualize three dimensional figures and calculating their volumes.
- ii) Draw the graph of functions in polar coordinates and level curves of functions of several variables.
- iii) Understand Limits, continuity and partial derivatives of functions of several variables.

● **GE2: Linear Algebra (UPC: 32355202)**

Course Objectives: The objective of the course is to introduce the concept of vectors in n . The concepts of linear independence and dependence, rank and linear transformations has been explained through matrices. Various applications of vectors in computer graphics and movements in a plane has also been introduced.

Course Learning Outcomes: This course will enable the students to:

- i) Visualize the space n in terms of vectors and the interrelation of vectors with matrices, and their application to computer graphics.
- ii) Learn about vector spaces, linear transformations, transition matrix and similarity.
- iii) Find approximate solution of inconsistent system of linear equations.

● **GE3: Linear Programming and Game Theory (UPC: 32355345)**

Course Objective: This course develops the ideas underlying the Simplex method computational techniques for linear programming and game theory, having applications in management, social science, industry, warfare, economics and financial sectors, etc.

Course Learning Outcomes: This course will enable the students to learn:

- i) The optimal solution for linear optimization problems subject to certain constraints.
- ii) The dual to a production problem with profits to be maximized to keep total cost down.
- iii) The transportation and Hungarian algorithm specially designed to solve the transportation and assignment problems, respectively.
- iv) The strategies for two-person, zero-sum game are obtained by solving two dual linear programming problems.

● **GE4: Elements of Analysis (UPC: 32355444)**

Course Objectives: The main aim of this course is to introduce the real number line, its completeness property and sequences. The relation between the convergent and Cauchy sequences has been explained. The concept of power series and its convergence has also been introduced.

Course Learning Outcomes: The students will be familiar with the concept of sequences, series. They will be able to test the convergence and divergence of series using the ratio test, Leibniz test. The concept of power series will help them to enrich their knowledge of elementary functions like $\exp(x)$, $\sin x$, $\cos x$.

Mathematics Course Wise Contents for B.A. Programme:

Core Papers

Paper 1: Calculus (UPC: 62351101)

Course Objectives: This course is primarily concerned with developing the students' understanding of the concepts of calculus and providing experience with its methods and applications to create mathematical models in order to arrive into an optimal solution.

Course Learning Outcomes: The students' who take this course will be able to:

- i) Understand continuity and differentiability in terms of limits.
- ii) Describe asymptotic behavior in terms of limits involving infinity.
- iii) Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the function.

Paper 2: Algebra (UPC: 62351201)

Course Objectives: Students will get conceptual understanding and the applicability of the subject matter. helps students to see how linear algebra can be applied to real-life situations. Modern concepts and notation are used to introduce the various aspects of linear equations, leading readers easily to numerical computations and applications.

Course Learning Outcomes: The course will enable the students to understand:

- i) Solving higher order algebraic equations.
- ii) Solving simultaneous linear equations with at most four unknowns.
- iii) Overview of abstract algebra, which is useful in their higher studies.

Paper 3: Analytic Geometry and Applied Algebra (UPC: 62354343)

Course Objectives: The course aims at identify curves and applying mathematical models in daily life problems studying geometric properties of different conic sections. The purpose of this course is to strengthen the mathematical skill along with the algebraic skills and concepts to assure success in the Algebra.

Course Learning Outcomes: The course will enable the students to:

- i) Identify and sketch curves.
- ii) Use three dimensional geometry using vectors.
- iii) Understand mathematical models to relate mathematics with daily life problems.

Paper 4: Analysis (UPC: 62354443)

Course Objectives: The course aims at building an understanding of convergence of sequence and series of real numbers and various methods/tools to test their convergence. The course also aims at building understanding of the theory of Riemann integration.

Course Learning Outcomes: The course will enable the students to:

- i) Understand basic properties of the field of real numbers.
- ii) To test convergence of sequence and series of real numbers.
- iii) Distinguish between the notion of integral as anti-derivative and Riemann integral.

Paper 5: DSE-1-Differential Equations (UPC: 62357502)

Course objectives: The course aims at introducing ordinary and partial differential equations to the students and finding their solutions using various techniques with the tools needed to model complex real-world situations.

Course learning outcomes: The course will enable the students to understand:

- i) Wronskian and its properties.
- ii) Method of variation of parameters and total differential equations.
- iii) Lagrange's method, and Charpit's method for solving PDE's of first order.

Paper 6: DSE-2-Numerical Methods (UPC: 62357602)

Course Objectives: The goal of this paper is to acquaint students for the study of certain algorithms that uses numerical approximation for the problems of solving polynomial equations, transcendental equations, linear system of equations, interpolation, and problems of ordinary differential equations.

Course Learning Outcomes: After completion of this course, students will be able to:

- i) Find the consequences of finite precision and the inherent limits of numerical methods.
- ii) Appropriate numerical methods to solve algebraic and transcendental equations.
- iii) How to solve first order initial value problems of ordinary differential equations numerically using Euler methods.

SEC Courses

SEC-1: Computer Algebra Systems (UPC: 62353327)

Course Objectives: This course aims at providing basic knowledge to Computer Algebra Systems (CAS) and their programming language in order to apply them for plotting functions, finding roots to polynomials, computing limits and other mathematical tools.

Course Learning Outcomes: This course will enable the students to use CAS:

- i) as a calculator;

- ii) for plotting functions;
- iii) for various applications of algebra, calculus and matrices.

SEC-2: Mathematical Typesetting System: LaTeX (UPC: 62353325)

Course Objectives: The purpose of this course is to help you begin using LaTeX, a mathematical typesetting system designed for the creation of beautiful books—and especially for books that contain a lot of mathematics, complicated symbols and formatting.

Course Learning Outcomes: This course will enable the students to:

- i) Create and typeset a LaTeX document;
- ii) Typeset a mathematical document;
- iii) Draw pictures in LaTeX, and create beamer presentations.

SEC-3: Statistical Software: R (UPC: 62353505)

Course Objectives: The purpose of this course is to help you begin using R, a powerful free software program for doing statistical computing and graphics. It can be used for exploring and plotting data, as well as performing statistical tests.

Course Learning Outcomes: This course will enable the students to:

- i) Use R as a calculator;
- ii) Read and import data in R.
- iii) Explore and describe data in R and plot various graphs in R.

SEC-4: Transportation and Network Flow Problems (UPC: 62353606)

Course Objectives: This course aims at providing applications of linear programming to solve real-life problems such as transportation problem, assignment problem, shortest-path problem, minimum spanning tree problem, maximum flow problem and minimum cost flow problem.

Course Learning Outcomes: This course will enable the students to solve:

- i) Transportation, Assignment and Travelling salesperson problems.
- ii) Network models and various network flow problems.

GE Courses

GE-1: General Mathematics–I (UPC: 62355503)

Course Objectives: The course aims at introducing number system, fundamental arithmetic operations, prime numbers and Pythagorean triplets to the students. The concept of matrices and determinants with their properties are also introduced.

Course Learning Outcomes: The course will enable the students to understand:

- i) The contributions of the Ancient Indian Mathematicians in the field of Algebra, Geometry, Trigonometry, Calculus and Astronomy.
- ii) The number systems and their properties, also Latin and Magic squares.
- iii) Matrices and determinants, inverse of a matrix, Cramer's rule to solve a system of linear equations.

GE-2: General Mathematics–II (UPC: 62355604)

Course Objectives: The course aims at introducing graph theory, perspective geometry and its uses in art, fractals in nature, Fibonacci sequences and their uses. The solutions to the linear system of equations using row operations of matrices are also introduced.

Course Learning Outcomes: The course will enable the students to understand:

- i) The contributions of remarkable Mathematicians in the field of Algebra, Analysis, Number theory, Calculus, Analytic geometry, Ordinary & partial differential equations and mechanics.
- ii) Perspective geometry and its uses in art, Fractals and Fibonacci sequences with applications.
- iii) Types of symmetry and patterns by looking at monuments/buildings/ornamental art.

COURSE: B.A. (Prog.) Computer Application DSE

Semester V

- **Paper Name: Programming in Python (UPC: 62347502)**

Course Objective:

The course introduces programming in Python and develops Python based solutions for simple problems.

Course Learning Outcomes: On successful completion of this course, a student will be able to:

- i. Select a suitable programming construct and inbuilt data structure for a situation.
- ii. Develop and document modular python programs.
- iii. Use classes and objects in application programs.

Semester VI

- **Paper Name: Information Security and Cyber Laws (UPC: 62347627)**

Course Objective:

The course aims to introduce the cyber threats, issues in information security and contemporary cyber laws.

Course Learning Outcomes: On successful completion of this course, a student will be able to:

- i. Enumerate issues in computer security.
- ii. Enumerate and describe common forms of attacks.
- iii. Describe the importance of security policy in the security framework.
- iv. Describe security related terms like cryptography, privacy, steganography.
- v. Describe the need for cyber laws.