COURSE OUTCOME 2023-24
DEPARTMENT OF MATHEMATICS

B.Sc.(Hons.) Mathematics

Sem	Type of Course	Course Name	Course Outcomes
I	Core	DSC-1: Algebra	CO1: Determine number of positive/negative real roots of a real polynomial. CO2: Solve cubic and quartic polynomial equations with special condition on roots and in general. CO3: Employ De-Moivre's theorem in a number of applications to solve numerical problems. CO4: Use modular arithmetic and basic properties of congruences. CO5: Recognize the algebraic structure, namely groups, and classify subgroups of cyclic groups.
I	Core	DSC-2: Elementary Real Analysis	CO1: Understand the fundamental properties of the real numbers, including completeness and Archimedean, and density property of rational numbers in $\mathbb{R}$. CO2: Learn to define sequences in terms of functions from $\mathbb{N}$ to a subset of $\mathbb{R}$ and find the limit. CO3: Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate the limit superior and limit inferior of a bounded sequence. CO4:Apply limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.
I	Core	DSC-3: Probability and Statistics	CO1: Understand some basic concepts and terminology - population, sample, descriptive and inferential statistics including stem-and-leaf plots, dotplots, histograms and boxplots. CO2: Learn about probability density functions and various univariate distributions such as binomial, hypergeometric, negative binomial, Poisson, normal, exponential and lognormal. CO3: Understand the remarkable fact that the empirical frequencies of so many natural populations, exhibit bell-shaped (i.e., normal) curves, using the Central Limit Theorem. CO4: Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

I	SEC	SEC-1: Statistics with R	CO1: After studying this course, students will be able to extract and Read data into R, manipulate, and analyse it. CO2: After studying this course, students will be able to debug, organize, and comment R code. CO3: After studying this course, students will be able to understand the R environment for downloading, installing, and using packages CO4: After studying this course, students will be able to do basic programming to write own functions CO5: After studying this course, students will be able to use loops CO6: After studying this course, students will be able to create standard and customized graphics CO7: After studying this course, students will be able to perform basic statistical operations and regression.
I	SEC	SEC-1: IT Skills and Data Analysis - I	CO1: Represent and interpret data in tabular and graphical forms CO2: Understand and interpret the measures of central tendency and dispersion. CO3: Use IT tools such as spreadsheets to visualize and analyze data.
I	SEC	SEC-1: Programming using Python	CO1: After studying this course, students will be able to interpret the basic representation of the data structures and sequential programming CO2: After studying this course, students will be able to gain knowledge of, and ability to use control framework terminologies. CO3: After studying this course, students will be able to work out using the core data structures as lists, dictionaries, tuples, and sets. CO4: After studying this course, students will be able to choose appropriate programming paradigms, interrupt and handle data using files to propose solutions through reusable modules CO5: After studying this course, students will be able to propose possible error-handling constructs for unanticipated states/inputs. CO6: After studying this course, students will be able to implements exemplary applications on real-world problems.
I	VAC	VAC-1: Vedic Mathematics-1	CO1: Overcome the fear of maths CO2: Improved critical thinking CO3: Familiarity with the mathematical underpinnings and techniques CO4: Ability to do basic maths faster and with ease. CO5: Appreciate the Mathematical advancements of Ancient India.

II	Core	DSC-4 Linear Algebra	CO1: Visualize the space $RRnn$ in terms of vectors and their interrelation with matrices. CO2: Familiarize with basic concepts in vector spaces, linear independence and span of vectors over a field. CO3: Learn about the concept of basis and dimension of a vector space. CO4: Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation with application to computer graphics.
II	Core	DSC-5: Calculus	CO1: The notion of limits, continuity and uniform continuity of functions. CO2: Geometrical properties of continuous functions on closed and bounded intervals. CO3: Applications of derivative, relative extrema and mean value theorems. CO4: Higher order derivatives, Taylor's theorem, indeterminate forms and tracing of curves.
II	Core	DSC-6: Ordinary Differential Equations	CO1: Learn the basics of differential equations and compartmental models. CO2: Formulate differential equations for various mathematical models. CO3: Solve first order non-linear differential equations, linear differential equations of higher order and system of linear differential equations using various techniques. CO4: Apply these techniques to solve and analyze various mathematical models.
II	SEC	SEC-1: IT Skills and Data Analysis - I	CO1: Represent and interpret data in tabular and graphical forms CO2: Understand and interpret the measures of central tendency and dispersion. CO3: Use IT tools such as spreadsheets to visualize and analyze data.
II	SEC	SEC-1: IT Skills and Data Analysis - II	CO1: Establish relationships between variables using correlation and regression analysis. CO2: Visualize functions and differentiate between linear and nonlinear functions. CO3: Use IT tools such as spreadsheets to visualize and analyze data.
II	SEC	SEC-1: Programming using Python	CO1: After studying this course, students will be able to interpret the basic representation of the data structures and sequential programming CO2: After studying this course, students will be able to gain knowledge of, and ability to use control framework terminologies. CO3: After studying this course, students will be able to work out using the core data structures as lists, dictionaries, tuples, and sets. CO4: After studying this course, students will be able to choose appropriate programming paradigms, interrupt and handle data using files to propose solutions through reusable modules

			CO5: After studying this course, students will be able to propose possible error-handling constructs for unanticipated states/inputs. CO6: After studying this course, students will be able to implements exemplary applications on real-world problems.
II	VAC	VAC-1: Vedic Mathematics-1	CO1: Overcome the fear of maths CO2: Improved critical thinking CO3: Familiarity with the mathematical underpinnings and techniques CO4: Ability to do basic maths faster and with ease. CO5: Appreciate the Mathematical advancements of Ancient India.
II	VAC	VAC-1: Vedic Mathematics-2	CO1: Think critically CO2: Find mathematical solution of algebraic expressions CO3: Solve system of linear equations and matrices faster and with ease. CO4: Appreciate the Mathematical advancements of Ancient India.
III	Core	DSC-7: Group Theory	CO1: Analyse the structure of 'small' finite groups, and examine examples arising as groups of permutations of a set, symmetries of regular polygons. CO2: Understand the significance of the notion of cosets, Lagrange's theorem and its consequences. CO3: Know about group homomorphisms and isomorphisms and to relate groups using these mappings. CO4: Express a finite abelian group as the direct product of cyclic groups of prime power orders. CO5: Learn about external direct products and its applications to data security and electric circuits.
III	Core	DCS-8: Riemann Integration	CO1: Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Riemann sums to the volume and surface of a solid of revolution. CO2: Get insight of integration by substitution and integration by parts. CO3: Know about convergence of improper integrals including, beta and gamma functions.
III	Core	DSC-9: Discrete Mathematics	CO1: Understand the notion of partially ordered set, lattice, Boolean algebra with applications. CO2: Handle the practical aspect of minimization of switching circuits to a great extent with the methods discussed in this course. CO3: Apply the knowledge of Boolean algebras to logic, set theory and probability theory.

III	DSE	DSE 1(ii) Mathematical Python	CO1: For numerical and symbolic computation in mathematical problems from calculus, algebra, and geometry. CO2: To tabulate and plot diverse graphs of functions and understand tracing of shapes, geometries, and fractals. CO3: To prepare smart documents with LaTeX interface.
III	DSE	DSE 1(iii) Number Theory	CO1: Use modular arithmetic in solving linear and system of linear congruence equations. CO2: Work with the number theoretic functions, their properties and their use. CO3: Learn the forms of positive integers that possess primitive roots and the Quadratic Reciprocity Law which deals with the solvability of quadratic congruences. CO4: Understand the public-key cryptosystems, in particular, RSA.
III	SEC	SEC-1: Statistics with R	CO1: After studying this course, students will be able to extract and Read data into R, manipulate, and analyse it. CO2: After studying this course, students will be able to debug, organize, and comment R code. CO3: After studying this course, students will be able to understand the R environment for downloading, installing, and using packages CO4: After studying this course, students will be able to do basic programming to write own functions CO5: After studying this course, students will be able to use loops CO6: After studying this course, students will be able to create standard and customized graphics CO7: After studying this course, students will be able to perform basic statistical operations and regression.
III	SEC	SEC-1: IT Skills and Data Analysis - I	CO1: Represent and interpret data in tabular and graphical forms CO2: Understand and interpret the measures of central tendency and dispersion. CO3: Use IT tools such as spreadsheets to visualize and analyze data.
III	SEC	SEC-1: Programming using Python	CO1: After studying this course, students will be able to interpret the basic representation of the data structures and sequential programming CO2: After studying this course, students will be able to gain knowledge of, and ability to use control framework terminologies. CO3: After studying this course, students will be able to work out using the core data structures as lists, dictionaries, tuples, and sets. CO4: After studying this course, students will be able to choose appropriate programming paradigms, interrupt and handle data using files to propose solutions through reusable modules CO5: After studying this course, students will be able to propose possible error-handling constructs for

			unanticipated states/inputs. CO6: After studying this course, students will be able to implements exemplary applications on real-world problems.
III	VAC	VAC-1: Vedic Mathematics-1	CO1: Overcome the fear of maths CO2: Improved critical thinking CO3: Familiarity with the mathematical underpinnings and techniques CO4: Ability to do basic maths faster and with ease. CO5: Appreciate the Mathematical advancements of Ancient India.
III	VAC	VAC-1: Vedic Mathematics-2	CO1: Think critically CO2: Find mathematical solution of algebraic expressions CO3: Solve system of linear equations and matrices faster and with ease. CO4: Appreciate the Mathematical advancements of Ancient India.
IV	Core	DSC-10: Sequences and Series of Functions	CO1: Learn about Cauchy criterion for uniform convergence and Weierstrass *M*-test for uniform convergence of series of real-valued functions. CO2: Know about the constraints for the inter changeability of differentiation, and integration with infinite sum of a series of functions. CO3: Handle the convergence of power series and properties of the limit function, including differentiation and integration of power series. CO4: Appreciate utility of polynomials in the space of continuous functions.
IV	Core	DSC-11: Multivariate Calculus	CO1: Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion. CO: Understand the maximization and minimization of multivariable functions subject to the given constraints on variables. CO3: Learn about inter-relationship amongst the line integral, double, and triple integral formulations. CO4: Familiarize with Green's, Stokes' and Gauss divergence theorems, and learn applications.

IV	Core	DSC-12: Numerical Analysis	CO1: Learn some numerical methods to find the zeroes of nonlinear functions of a single variable, up to a certain given level of precision. CO2: Learn Gauss−Jacobi, Gauss−Seidel methods to solve system of linear equations. CO3: Get aware of using interpolation techniques, for example in finding values of a tabulated function at points which are not part of the table. CO4 Learn finding numerical solutions of difference equations which are obtained converting differential equations using techniques from calculus.
IV	DSE	DSE-2(ii): Mathematical Modeling	CO1: Understand the methodology of solving SIR models for disease spread. CO2: Learn significance of dieting model that provides important insights and guides to a biomedical issue that is of interest to the general public. CO3: Understand nonlinear systems and phenomena with stability analysis ranges from phase plane analysis to ecological and mechanical systems. CO4: Use Monte Carlo simulation technique to approximate area under a given curve, and volume under a given surface.
IV	SEC	SEC-1: IT Skills and Data Analysis - I	CO1: Represent and interpret data in tabular and graphical forms CO2: Understand and interpret the measures of central tendency and dispersion. CO3: Use IT tools such as spreadsheets to visualize and analyze data.
IV	SEC	SEC-1: IT Skills and Data Analysis - II	CO1: Establish relationships between variables using correlation and regression analysis. CO2: Visualize functions and differentiate between linear and nonlinear functions. CO3: Use IT tools such as spreadsheets to visualize and analyze data.

IV	SEC	SEC-1: Programming using Python	CO1: After studying this course, students will be able to interpret the basic representation of the data structures and sequential programming CO2: After studying this course, students will be able to gain knowledge of, and ability to use control framework terminologies. CO3: After studying this course, students will be able to work out using the core data structures as lists, dictionaries, tuples, and sets. CO4: After studying this course, students will be able to choose appropriate programming paradigms, interrupt and handle data using files to propose solutions through reusable modules CO5: After studying this course, students will be able to propose possible error-handling constructs for unanticipated states/inputs. CO6: After studying this course, students will be able to implements exemplary applications on real-world problems.
IV	VAC	VAC-1: Vedic Mathematics-1	CO1: Overcome the fear of maths CO2: Improved critical thinking CO3: Familiarity with the mathematical underpinnings and techniques CO4: Ability to do basic maths faster and with ease. CO5: Appreciate the Mathematical advancements of Ancient India.
IV	VAC	VAC-1: Vedic Mathematics-2	CO1: Think critically CO2: Find mathematical solution of algebraic expressions CO3: Solve system of linear equations and matrices faster and with ease. CO4: Appreciate the Mathematical advancements of Ancient India.
V	Core	BMATH511: Metric Spaces	CO1: Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces. CO2: Analyse how a theory advances from a particular frame to a general frame. CO3: Appreciate the mathematical understanding of various geometrical concepts, viz. balls or connected sets etc. in an abstract setting. CO4: Know about Banach fixed point theorem, whose far-reaching consequences have resulted into an independent branch of study in analysis, known as fixed point theory. CO5: Learn about the two important topological properties, namely connectedness and compactness of metric spaces.

V	Core	BMATH512: Group Theory-II	CO1: Learn about automorphisms for constructing new groups from the given group. CO2: Learn about the fact that external direct product applies to data security and electric circuits. CO3: Understand fundamental theorem of finite abelian groups. CO4: Be familiar with group actions and conjugacy. CO5: Understand Sylow theorems and their applications in checking non simplicity.
V	DSE	DSE-1(i): Numerical Analysis	CO1: Learn 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. CO2: Know about methods to solve system of linear equations, such as Gauss−Jacobi, Gauss−Seidel and SOR methods. CO3: Interpolation techniques to compute the values for a tabulated function at points not in the table. CO4: Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.
V	DSE	DSE-1(iii): C++ Programming for Mathematics	CO1: Understand and apply the programming concepts of C++ which is important to mathematical investigation and problem solving. CO2: Learn about structured data-types in C++ and learn about applications in factorization of an integer and understanding Cartesian geometry and Pythagorean triples. CO3: Use of containers and templates in various applications in algebra. CO4: Use mathematical libraries for computational objectives. CO5: Represent the outputs of programs visually in terms of well formatted text and plots.

V	DSE	DSE-2(i): Probability Theory and Statistics	CO1: Learn about probability density and moment generating functions. CO2: Know about various univariate distributions such as Bernoulli, Binomial, Poisson, gamma and exponential distributions. CO3: Learn about distributions to study the joint behavior of two random variables. CO4: Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression. CO5: Understand central limit theorem, which helps to understand the remarkable fact that: the empirical frequencies of so many natural populations, exhibit a bell-shaped curve, i.e., a normal distribution.
V	DSE	DSE-2(ii): Discrete Mathematics	CO1: Understand the notion of ordered sets and maps between ordered sets. CO2: Learn about lattices, modular and distributive lattices, sublattices and homomorphisms between lattices. CO3: Become familiar with Boolean algebra, Boolean homomorphism, Karnaugh diagrams, switching circuits and their applications. CO4: Learn about basics of graph theory, including Eulerian graphs, Hamiltonian graphs. CO5: Learn about the applications of graph theory in the study of shortest path algorithms.
VI	Core	BMATH613: Complex Analysis	CO1: Learn the significance of differentiability of complex functions leading to the understanding of Cauchy−Riemann equations. CO2: Learn some elementary functions and valuate the contour integrals. CO3: Understand the role of Cauchy−Goursat theorem and the Cauchy integral formula. CO4: 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.
VI	Core	BMATH614: Ring Theory and Linear Algebra-II	CO1: Appreciate the significance of unique factorization in rings and integral domains. CO2: Compute 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.

			CO3: Compute inner products and determine orthogonality on vector spaces, including Gram−Schmidt orthogonalization to obtain orthonormal basis. CO4: Find the adjoint, normal, unitary and orthogonal operators.
VI	DSE	DSE-3 (iii): Biomathematics	CO1: Learn the development, analysis and interpretation of bio mathematical models such as population growth, cell division, and predator-prey models. CO2: Learn about the mathematics behind heartbeat model and nerve impulse transmission model. CO3: Appreciate the theory of bifurcation and chaos. CO4: Learn to apply the basic concepts of probability to molecular evolution and genetics.
VI	DSE	DSE-4 (ii): Linear Programming and Applications	CO1: Learn about the graphical solution of linear programming problem with two variables. CO2: Learn about the relation between basic feasible solutions and extreme points. CO3: Understand the theory of the simplex method used to solve linear programming problems. CO4: Learn about two-phase and big-M methods to deal with problems involving artificial variables. CO5: Learn about the relationships between the primal and dual problems. CO6: Solve transportation and assignment problems. CO7: Apply linear programming method to solve two-person zero-sum game problems.

GENERIC ELECTIVE (GE) Courses for Honours Courses (For students other than B.Sc. (Hons.) Mathematics)

Sem	Type of Course	Course Name	Course Outcomes
I	GE	GE-1: Fundamentals of Calculus	CO1: Understand continuity and differentiability in terms of limits. CO2: Describe asymptotic behavior in terms of limits involving infinity. CO3: Understand the importance of mean value theorems and its applications. CO4: Learn about Maclaurin's series expansion of elementary functions. CO5: Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the polynomial and rational functions.
II	GE	GE-2: Introduction to Linear Algebra	CO1: Visualize the space $RRnn$ in terms of vectors and the interrelation of vectors with matrices. CO2: Understand important uses of eigenvalues and eigenvectors in the diagonalization of matrices. CO3: Familiarize with concepts of bases,

			dimension and minimal spanning sets in vector spaces. CO4: Learn about linear transformation and its corresponding matrix.
III	GE	GE-3: Differential Equations	CO1: Solve the exact, linear, Bernoulli equations, find orthogonal trajectories and solve rate problems. CO2: Apply the method of undetermined coefficients and variation of parameters to solve linear differential equations. CO3: Solve Cauchy-Euler equations and System of linear differential equations. CO4: Formulate and solve various types of first and second order partial differential equations.
IV	GE	GE-4: Linear Programming	CO1: Learn about the simplex method used to find optimal solutions of linear optimization problems subject to certain constraints. CO2: Write the dual of a linear programming problem. CO3: Solve the transportation and assignment problems. CO4: Learn about solution of rectangular games using graphical method and dominance. CO5: Formulate game to a pair of associated prima-dual linear programming problems.

MATHEMATICS COURSES FOR B.A. (PROG.)

Sem	Type of Course	Course Name	Course Outcomes
I	Core Major	DSC-1: Elements of Discrete Mathematics	CO1: Understand the basic concepts of sets, relations, functions, and induction. CO2: Understand mathematical logic and logical operations to various fields. CO3: Understand the notion of order and maps between partially ordered sets. CO4: Minimize a Boolean polynomial and apply Boolean algebra techniques to decode switching circuits.
I	Core Minor	DSC-1 Topics in Calculus	CO1: Understand continuity and differentiability in terms of limits and graphs of certain functions. CO2: Describe asymptotic behaviour in terms of limits involving infinity. CO3: Use of derivatives to explore the behaviour of a given function locating and classify its extrema and graphing the function. CO4: Apply the concepts of asymptotes, and inflexion points in tracing of cartesian curves. CO5: Compute the reduction formulae of standard transcendental functions with applications

II	Core Major	DSC-2: Analytic Geometry	CO1: Learn concepts in two-dimensional geometry. CO2: Identify and sketch conics namely, ellipse, parabola and hyperbola. CO3: Learn about three-dimensional objects such as straight lines and planes using vectors, spheres, cones and cylinders.
II	Core Minor	DSC-2 (Discipline-A-2) Elementary Linear Algebra	CO1: To introduce the concept of vectors in R^n. CO2: Understand the nature of solution of system of linear equations. CO3: To view the $m \times n$ matrices as a linear function from R^n to R^m and vice versa. CO4: To introduce the concepts of linear independence and dependence, rank and linear transformations has been explained through matrices. CO4: Get an overview of abstract algebra by learning about algebraic structures namely, groups, rings and vector spaces.
III	Core Major	DSC-3: Theory of Equations and Symmetries	CO1: Understand the nature of the roots of polynomial equations and their symmetries. CO2: Solve cubic and quartic polynomial equations with special condition on roots and in general. CO3: Find symmetric functions in terms of the elementary symmetric polynomials.
III	Core Minor	DSC-3: Differential Equations	CO1: Solve the exact, linear, Bernoulli equations, find orthogonal trajectories and solve rate problems. CO2: Apply the method of undetermined coefficients and variation of parameters to solve linear differential equations. CO3: Solve Cauchy-Euler equations and System of linear differential equations. CO4: Formulate and solve various types of first and second order partial differential equations
IV	Core Major	DSC-4: Introduction to Graph Theory	CO1: Good familiarity with all initial notions of graph theory and related results and seeing them used for some real-life problems. CO2: Learning notion of trees and their enormous usefulness in various problems. CO3: Learning various algorithms and their applicability. CO4: Studying planar graphs, Euler theorem associated to such graphs and some useful applications like coloring of graphs.

IV	Core Minor	DSC-4 (Discipline A-4): Abstract Algebra	CO1: Appreciate ample types of groups present around us which explains our surrounding better, and classify them as abelian, cyclic and permutation groups. CO2 Explain the significance of the notion of cosets, normal subgroups and homomorphisms. CO3: Understand the fundamental concepts of rings, subrings, fields, ideals, and factor rings.
V	DSE	DSE-1 (i): Statistics	CO1: Determine moments and distribution function using moment generating functions. CO2: Learn about various discrete and continuous probability distributions. CO3: Know about correlation and regression for two variables, weak law of large numbers and central limit theorem. CO4: Test validity of hypothesis, using Chi-square, F and t-tests, respectively in sampling distributions.
V	GE	GE-1 General Mathematics-I	CO1: Learn about the contributions of the ancient Indian mathematicians in the field of algebra, geometry, trigonometry, calculus and astronomy. CO2: Know more about prime numbers, Fermat's last theorem, Latin and magic squares. CO3: Understand the various types of matrices, operations of matrices, and Cramer's rule to solve a system of linear equations.
VI	DSE	DSE-2 (i): Numerical Methods	CO1: Find the consequences of finite precision and the inherent limits of numerical methods. CO2: Appropriate numerical methods to solve algebraic and transcendental equations. CO3: Solve first order initial problems of ordinary differential equations numerically using Euler methods.
VI	GE	GE-2: General Mathematics – II	CO1: Learn about the contributions of remarkable mathematicians in the field of algebra, analysis, number theory, calculus, analytic geometry, differential equations and mechanics. CO2: Understand basics of graph theory, functions and their graphs, perspective geometry and its uses in art, fractals and Fibonacci sequences with applications. CO3: Learn about types of symmetry and patterns by looking at monuments/buildings/ornamental art. CO4: Solve systems of linear equations using Gauss elimination and Gauss−Jordon methods, and rank of matrices.