Course Outcomes – Program Outcomes (COPO) Mapping

Program Outcomes (PO): CBCS: B.Sc.(Hons.) Mathematics

Learning Outcomes based Curriculum Framework (LOCF)

The current focus in higher education is to shift from teacher-centric approach to learnercentric approach. For this as one of the aims, UGC has introduced the learning outcomes based curriculum framework for undergraduate education. The learning outcomes based curriculum framework for B.Sc. (Hons.) Mathematics is prepared keeping this in view. The framework is expected to provide a student with knowledge and skills in mathematics along with generic and transferable skills in other areas that help in personal development, employment and higher education in the global world. The programme-learning outcomes and course learning outcomes have been clearly specified to help prospective students.

ABBREVIATIONS / NOMENCLATURE

Sno.	Nomenclature	Description	Aggregate Courses
1	PO	Program Outcome	PO1, PO2,PO3, PO4, PO5
2	CO	Course Outcome	CO1, CO2, CO3, CO4, CO5, CO6
3	DSC	Core Courses	CC1,CC2, CC3, CC4, CC5, CC6, CC7, CC8, CC9, CC10. CC11, CC12, CC13, CC14
4	DSE	Discipline Specific Electives	DSE1, DSE2, DSE3, DSE4
5	GE	General Electives	GE1 , GE2, GE3, GE4
6	BAP	B.A(Prog.)	BAP1, BAP2, BAP3, BAP4

Sno.	Program Outcomes (PO): B.Sc.(Hons.) Mathematics	Statements
1.	**PO1**	Communicate mathematics effectively by written, computational and graphic means.
2.	**PO2**	Create mathematical ideas from basic axioms.
3.	**PO3**	Gauge the hypothesis, theories, techniques and proofs provisionally.
4.	**PO4**	Utilize mathematics to solve theoretical and applied problems by critical understanding, analysis and synthesis.
5.	**PO5**	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.

Course Outcomes (CO): B.Sc.(Hons.) Mathematics

SEMESTER 1: **CC1: Calculus**			
Unique Paper Code	**Name of the Paper**	**Course Outcome: CO**	**Statement**
32351101	**CC1: Calculus**	CO1	Learn first and second derivative tests for relative extrema and apply the knowledge in problems in business, economics and life sciences.
		CO2	Sketch curves in a plane using its mathematical properties in the different coordinate systems of reference.
		CO3	Compute area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.
		CO4	Understand the calculus of vector functions and its use to develop the basic principles of planetary motion.
CC2: Algebra			
32351102	**CC2: Algebra**	CO1	Employ De Moivre's theorem in a number of applications to solve numerical problems.
		CO2	Learn about equivalent classes and cardinality

			of a set.
		CO3	Use modular arithmetic and basic properties of congruences.
		CO4	Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix.
		CO5	Find eigenvalues and corresponding eigenvectors for a square matrix.
GE1 (FOR HONOURS): Calculus			
23355101	**GE1: Calculus**	CO1	Sketch the curves in Cartesian and polar coordinates as well as learn techniques of sketching the conics.
		CO2	Visualize three dimensional figures and calculate their volumes and surface areas.
		CO3	Understand limits, continuity and derivatives of functions of several variable and vector-valued functions.
BA PROGRAM: Calculus			
62351101	**BAP1: Calculus**	CO1	Understand continuity and differentiability in terms of limits.
		CO2	Describe asymptotic behavior in terms of limits involving infinity.
		CO3	Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the function.
		CO4	Understand the importance of mean value theorems.
		CO5	Learn about Maclaurin's series expansion of elementary functions.

COPO MAPPING

	SEMESTER I : COPO MAPPING					
Papers	Program Outcome : PO					
	Course Outcome: CO	PO1	PO2	PO3	PO4	PO5
	CO1				✓	✓
CC1	CO2	✓	✓	✓		

	CO3	✓		✓	✓	
	CO4		✓		✓	
	CO5			✓		✓
CC2	CO1		✓		✓	
	CO2				✓	
	CO3			✓		✓
	CO4				✓	
	CO5				✓	
GE1	CO1	✓			✓	
	CO2	✓	✓		✓	
	CO3				✓	✓
BAP1	CO1			✓	✓	
	CO2		✓		✓	✓
	CO3	✓	✓			
	CO4				✓	
	CO5				✓	✓

SEMESTER II: CC3: Real Analysis			
Unique Paper Code	**Name of the Paper**	**Course Outcome: CO**	**Statement**
32351201	**CC3:Real Analysis**	CO1	Understand many properties of the real line $\mathbb{R}$, including completeness and Archimedean properties.
		CO2	Learn to define sequences in terms of functions from $\mathbb{N}$ to a subset of $\mathbb{R}$. systems of reference.
		CO3	Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
		CO4	Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.
CC4: Differential Equations			

32351202	**CC4: Differential Equations**	CO1	Learn basics of differential equations and mathematical modeling.
		CO2	Formulate differential equations for various mathematical models.
		CO3	Solve first order non-linear differential equations and linear differential equations of higher order using various techniques.
		CO4	Apply these techniques to solve and analyze various mathematical models.
GE2 (FOR HONOURS): Linear Algebra			
32355202	**GE2: Linear Algebra**	CO1	Visualize the space R^n in terms of vectors and the interrelation of vectors with matrices, and their application to computer graphics.
		CO2	Familiarize with concepts in vector spaces, namely, basis, dimension and minimal spanning sets.
		CO3	Learn about linear transformations, transition matrix and similarity.
		CO4	Learn about orthogonality and to find approximate solution of inconsistent system of linear equations.
BA PROGRAM: Algebra			
62351201	**BAP2: Algebra**	CO1	Solving higher order algebraic equations.
		CO2	Become aware of De Moivre's theorem and its applications.
		CO3	Solving simultaneous linear equations with at most four unknowns.
		CO4	Get an overview of abstract algebra by learning about algebraic structures namely, groups, rings and vector spaces.

COPO MAPPING

	SEMESTER II : COPO MAPPING					
Papers	Program Outcome : PO					
	Course Outcome: CO	PO1	PO2	PO3	PO4	PO5
	CO1	✓	✓	✓		
CC3	CO2			✓	✓	

	CO3			✓	✓	
	CO4		✓	✓	✓	
CC4	CO1	✓			✓	
	CO2		✓		✓	
	CO3				✓	✓
	CO4			✓	✓	✓
GE2	CO1		✓			
	CO2			✓	✓	
	CO3		✓		✓	
	CO4			✓	✓	
BAP2	CO1				✓	
	CO2			✓		✓
	CO3		✓		✓	
	CO4		✓		✓	

SEMESTER III: **CC5: Theory of Real Functions**			
Unique Paper Code	**Name of the Paper**	**Course Outcome: CO**	**Statement**
32351301	**CC5: Theory of Real Functions**	CO1	Have a rigorous understanding of the concept of limit of a function.
		CO2	Learn about continuity and uniform continuity of functions defined on intervals.
		CO3	Understand geometrical properties of continuous functions on closed and bounded intervals.
		CO4	Learn extensively about the concept of differentiability using limits, leading to a better understanding for applications.
		CO5	Know about applications of mean value theorems and Taylor's theorem.
CC6: Group Theory-I			
32351302	**CC6: Group Theory-I**	CO1	Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.
		CO2	Link the fundamental concepts of groups and symmetrical figures.
		CO3	Analyze the subgroups of cyclic groups and

			classify subgroups of cyclic groups.
		CO4	Explain the significance of the notion of cosets, normal subgroups and factor groups.
		CO5	Learn about Lagrange's theorem and Fermat's Little theorem.
		CO6	Know about group homomorphisms and group isomorphisms.
CC7: Multivariate Calculus			
32351303	**CC7: Multivariate Calculus**	CO1	Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
		CO2	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.
GE3 (FOR HONOURS): Linear Programming and Game Theory			
32355345	**GE3: Linear Programming and Game Theory**	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 the solution of rectangular games using graphical method and using the solution of a pair of associated prima-dual linear programming problems.
BA PROGRAM: Analytic Geometry and Applied Algebra			
62354343	**BAP3: Analytic Geometry and Applied Algebra**	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

			spheres, conicoids, straight lines and planes using vectors
		CO4	Understand various applications of algebra in design of experiments, modelling of matching jobs, checking spellings, network reliability and scheduling of meetings.

COPO MAPPING

	SEMESTER III : COPO MAPPING					
Papers	Program Outcome : PO					
	Course Outcome: CO	PO1	PO2	PO3	PO4	PO5
CC5	CO1		✓		✓	
	CO2		✓	✓	✓	
	CO3		✓	✓		
	CO4				✓	✓
	CO5				✓	
CC6	CO1		✓	✓	✓	
	CO2	✓				
	CO3		✓	✓	✓	
	CO4			✓	✓	
	CO5				✓	✓
	CO6			✓	✓	
CC7	CO1	✓		✓		
	CO2		✓		✓	
	CO3			✓	✓	
	CO4		✓			✓
GE3	CO1	✓		✓	✓	
	CO2		✓		✓	
	CO3			✓	✓	
	CO4		✓		✓	✓
BAP3	CO1	✓		✓		
	CO2			✓	✓	
	CO3			✓	✓	
	CO4		✓		✓	✓

SEMESTER IV: **CC8: Partial Differential Equations**			
Unique	**Name of the**	**Course**	

Paper Code	Paper	Outcome: CO	Statement
32351401	**CC8: Partial Differential Equations**	CO1	Formulate, classify and transform first order PDEs into canonical form.
		CO2	Learn about method of characteristics and separation of variables to solve first order PDE's.
		CO3	Classify and solve second order linear PDEs.
		CO4	Learn about Cauchy problem for second order PDE and homogeneous and nonhomogeneous wave equations.
		CO5	Apply the method of separation of variables for solving many well-known second order PDEs.
CC9: Riemann Integration & Series of Functions			
32351402	**CC9: Riemann Integration & Series of Functions**	CO1	Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Fundamental theorems of integration.
		CO2	Know about improper integrals including, beta and gamma functions.
		CO3	Learn about Cauchy criterion for uniform convergence and Weierstrass M-test for uniform convergence.
		CO4	Know about the constraints for the inter-changeability of differentiability and integrability with infinite sum.
		CO5	Approximate transcendental functions in terms of power series as well as, differentiation and integration of power series.
CC10: Ring Theory & Linear Algebra-I			
32351403	**CC10: Ring Theory & Linear Algebra-I**	CO1	Learn about the fundamental concept of rings, integral domains and fields.
		CO2	Know about ring homomorphisms and isomorphisms theorems of rings.
		CO3	Learn about the concept of linear independence of vectors over a field, and the dimension of a vector space.
		CO4	Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation, and the change of coordinate matrix.

GE4 (FOR HONOURS): Elements of Analysis			
32355444	**GE4: Elements of Analysis**	CO1	Understand the real numbers and their basic properties.
		CO2	Be familiar with convergent and Cauchy sequences.
		CO3	Test the convergence and divergence of infinite series of real numbers.
		CO4	Learn about power series expansion of some elementary functions.
BA PROGRAM: Analysis			
62354445	**BAP4: Analysis**	CO1	Understand basic properties of the field of real numbers.
		CO2	Examine continuity and uniform continuity of functions using sequential criterion.
		CO3	Test convergence of sequence and series of real numbers.
		CO4	Distinguish between the notion of integral as anti-derivative and Riemann integral.

COPO MAPPING

	SEMESTER IV : COPO MAPPING					
Papers	Program Outcome : PO					
	Course Outcome: CO	PO1	PO2	PO3	PO4	PO5
CC8	CO1	✓	✓			
	CO2			✓	✓	
	CO3		✓	✓	✓	
	CO4			✓	✓	✓
	CO5			✓	✓	
CC9	CO1		✓	✓		
	CO2			✓	✓	
	CO3				✓	
	CO4			✓	✓	
	CO5			✓	✓	✓
CC10	CO1		✓	✓		
	CO2			✓	✓	
	CO3			✓	✓	✓
	CO4			✓	✓	✓

GE4	CO1	✓	✓			
	CO2			✓	✓	
	CO3			✓	✓	
	CO4			✓	✓	✓
BAP4	CO1	✓	✓			
	CO2		✓	✓		
	CO3		✓	✓	✓	
	CO4			✓	✓	✓

SEMESTER V: CC11: Metric Spaces			
Unique Paper Code	**Name of the Paper**	**Course Outcome: CO**	**Statement**
32351501	**CC11: 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. order PDEs.
CC12: Group Theory-II			
32351502	**CC12: 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 in S^n.
		CO5	Understand Sylow theorems and their applications in checking nonsimplicity.

DSE1 : Numerical Analysis			
32357501	**DSE1: 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.
DSE2 : Probability Theory and Statistics			
32357507	**DSE2: 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.
BA PROGRAM: DSE-1 : Statistics			
62357503	**DSE1: Statistics**	CO1	Understand basic properties of the field of real numbers.
		CO2	Examine continuity and uniform continuity of functions using sequential criterion.
		CO3	Test convergence of sequence and series of real numbers.
		CO4	Distinguish between the notion of integral as anti-derivative and Riemann integral.

COPO MAPPING

	SEMESTER V : COPO MAPPING					
Papers	Program Outcome : PO					
	Course Outcome: CO	PO1	PO2	PO3	PO4	PO5
CC11	CO1	✓	✓			
	CO2			✓	✓	
	CO3			✓	✓	
	CO4			✓	✓	✓
	CO5			✓	✓	
CC12	CO1			✓	✓	
	CO2		✓	✓		
	CO3		✓	✓	✓	
	CO4		✓	✓		
	CO5			✓		✓
DSE1	CO1	✓	✓			
	CO2		✓	✓		
	CO3			✓	✓	
	CO4			✓	✓	✓
DSE2	CO1		✓	✓		
	CO2			✓	✓	
	CO3				✓	
	CO4			✓	✓	✓
BAP(DSE-1)	CO1		✓	✓		
	CO2				✓	
	CO3			✓	✓	
	CO4				✓	✓

SEMESTER VI: CC13: Complex Analysis			
Unique Paper Code	**Name of the Paper**	**Course Outcome: CO**	**Statement**
32351601	**CC13: 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.
CC14: Ring Theory and Linear Algebra-II			
32351602	**CC14: 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.
DSE3: Introduction to Information Theory and Coding			
35357615	**DSE3: Introduction to Information Theory and Coding**	CO1	Learn about the basic concepts of information theory.
		CO2	Know about basic relationship among different entropies and interpretation of Shannon's fundamental inequalities.
		CO3	Learn about the detection and correction of errors while transmission.
		CO4	Representation of a linear code by matrices.
		CO5	Learn about encoding and decoding of linear codes.
DSE4 : Linear Programming and Applications			
35357616	**DSE4: 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.
BA PROGRAM: DSE2 : Differential Equations			
62357604	**DSE2: Differential Equations**	CO1	Solve ODE's and know about Wronskian and its properties.
		CO2	Method of variation of parameters and total differential equations.
		CO3	Solve linear PDE's of first order.
		CO4	Understand Lagrange's and Charpit's methods for solving nonlinear PDE's of first order.

COPO MAPPING

	SEMESTER VI : COPO MAPPING					
Papers	Program Outcome : PO					
	Course Outcome: CO	PO1	PO2	PO3	PO4	PO5
CC13	CO1	✓	✓			
	CO2			✓		
	CO3			✓		
	CO4			✓	✓	✓
CC14	CO1	✓	✓			
	CO2			✓		
	CO3			✓		
	CO4			✓	✓	✓
DSE3	CO1	✓				
	CO2		✓	✓		
	CO3			✓		
	CO4			✓	✓	✓
	CO5				✓	✓
DSE4	CO1	✓	✓			
	CO2			✓		
	CO3			✓		
	CO4			✓	✓	✓

	CO5				✓	
BAP(DSE-2)	CO1	✓	✓			
	CO2			✓		
	CO3		✓	✓		
	CO4			✓	✓	
	CO5				✓	✓