Salesian College
Sonada & Siliguri

Department of Mathematics

Programme and Course Learning Outcomes

Contents

1 Programme Learning Outcomes [1]

1. Bachelor's degree in Mathematics is the culmination of in-depth knowledge of Algebra, Calculus, Geometry, Differential Equations and several other branches of Mathematics. This also leads to study of related areas like Computer Science and Statistics. Thus, this programme helps learners in building a solid foundation for higher studies in Mathematics.
2. The skills and knowledge gained has intrinsic beauty, which also leads to proficiency in analytical reasoning. This can be utilised in modelling and solving real life problems.
3. Students undergoing this programme learn to logically question assertions, to recognise patterns and to distinguish between essential and irrelevant aspects of problems. They also share ideas and insights while seeking and benefiting from knowledge and insight of others. This helps them to learn behave responsibly in a rapidly changing interdependent society.
4. Students completing this programme will be able to present Mathematics clearly and precisely, make vague ideas precise by formulating them in the language of Mathematics, describe Mathematical ideas from multiple perspectives and explain fundamental concepts of Mathematics to non-mathematicians.
5. Completion of this programme will also enable the learners to join teaching profession in primary and secondary schools.
6. This programme will also help students to enhance their employability for Government jobs, jobs in banking, insurance and investment sectors, data analyst jobs and jobs in various other public and private enterprises.

2 Course Learning Outcomes

2.1 Core Course 1: Calculus, Geometry and Differential Equations

On completion of the course, a student should be able to

(a) describe the concepts and applications of derivatives and higher order derivatives,
(b) find the n^{th} derivatives of functions,
(c) acquire the concept of asymptotes and envelopes,
(d) calculate limits in indeterminate forms by a repeated use of L'Hospital's rule,
(e) determine concavity and convexity of a function from its graph and from its second derivative,
(f) understand the concepts & advanced topics of different Conic sections/Conicoids related to two & three dimensional geometry,
(g) learn to trace a curve.
(h) solve first order ordinary differential equations utilizing the standard techniques for separable, exact, linear, homogeneous or Bernoulli cases.

2.2 Core Course 2: Algebra

On completion of the course, a student should be able to

(a) find the n^{th} root of unity and use the concept of De-Moivre's theorem to express e^{ix} into $\cos x + i \sin x$ form,
(b) find different types of inequalities using theorem on means, m^{th} power theorem,
(c) determine equivalence relations on sets and corresponding equivalence classes,
(d) work with functions and in particular bijections, direct and inverse images and inverse functions,
(e) acquire the knowledge of the relationship between coefficients and roots of an equation,
(f) apply the theoretic knowledge of different methods for finding the roots of a given equation into practical problems,
(g) learn the basic concept of number theory in order to use it in further for analytic number theory,
(h) solve the matrix equation $Ax = b$ using row and column operations,

(i) find the characteristic equation, eigenvalues and corresponding eigenvectors of a given matrix, Caley-Hamilton theorem.
(j) understand, know and identify examples of Vector spaces and subspaces,
(k) understand different definitions of rank of a matrix,
(l) understand a linear transformation,
(m) associate a matrix to a given linear transformation w.r.t. given ordered bases,
(n) prove and apply rank-nullity theorem,
(o) understand concept of isomorphism of spaces.

2.3 Core Course 3: Real Analysis

On completion of the course, a student should be able to
(a) explain the basic idea of real numbers,
(b) describe fundamental properties of the real numbers that lead to the formal development of real analysis,
(c) describe the real line as a complete, ordered field,
(d) determine the basic topological properties of subsets of the real numbers,
(e) describe the terms limit and limit points of a set and explain open and closed sets,
(f) distinguish between countable and uncountable sets and give examples for them,
(g) explain the idea about sequences and monotone property,
(h) acquire the basic knowledge of convergence and divergence,
(i) use the knowledge of convergence into problems,
(j) demonstrate an understanding of limits and how they are used in sequences, series,
(k) apply various theorems on the existence of limits of sequences and their evaluations,
(l) apply the knowledge of convergence to problems and the various theorems on convergence, absolute convergence and non-absolute convergence,
(m) comprehend rigorous arguments developing the theory underpinning real analysis,
(n) construct rigorous mathematical proofs of basic results in real analysis,
(o) appreciate how abstract ideas and rigorous methods in mathematical analysis can be applied to important practical problems,
(p) produce rigorous proofs of results that arise in the context of real analysis.

2.4 Core Course 4: Differential Equations and Vector Calculus

On completion of the course, a student should be able to
(a) solve second order linear homogeneous and non-homogeneous differential equations with constant coefficients,
(b) understand the basic knowledge of complimentary functions and particular integrals,
(c) obtain power series solutions of differential equations,
(d) develop the ability to apply differential equations to theoretical problems,
(e) investigate the qualitative behaviour of solutions of systems of differential equations,
(f) do the phase plane analysis,
(g) find the Vector triple product and product of four vectors and use it to find the equation of straight lines, planes in vector form.

2.5 Core Course 5: Theory of Real Functions and Introduction to Metric Spaces

On completion of the course, a student should be able to
(a) explain continuity and discontinuity of various functions in different contexts,
(b) understand, know and prove different properties of a continuous function,
(c) distinguish uniform continuity from pointwise continuity,
(d) understand the meaning of derivative of a function,
(e) understand Taylor's theorem associated with differentiability,
(f) understand and appreciate the motivation and definition of Metric spaces,
(g) understand the basic concepts of open sets, closed sets in a metric spaces,
(h) be familiar with convergence in metric spaces and theorems on convergence,

(i) explore various properties of complete metric spaces and relate them with convergence of sequences,
(j) understand and apply the knowledge of metric spaces various contexts.

2.6 Core Course 6: Group Theory – I

On completion of the course, a student should be able to
(a) verify relationships between operations satisfying various properties (e.g. commutative property),
(b) assess properties implied by the definitions of groups,
(c) acquire the basic knowledge and the structure of group, subgroup and cyclic groups,
(d) explain the significance of the notion of a Normal subgroup,
(e) analyse and demonstrate examples of subgroups, normal subgroups and quotient groups,
(f) use Lagranges theorem to analyse the cyclic subgroups of a group,
(g) acquire the notion of permutations and operations on them,
(h) Prove Cayleys theorem and understand its applications,
(i) explain the terms isomorphism and homomorphism,
(j) develop ideas about homomorphism and isomorphism.

2.7 Core Course 7: Riemann Integration and Series of Functions

On completion of the course, a student should be able to
(a) understand partitions and their refinements,
(b) understand Riemann integrability and theorems on integrability and applications,
(c) understand fundamental theorem of Integral Calculus,
(d) explain convergence of a series,
(e) distinguish between Pointwise convergence and Uniform Convergence,
(f) check uniform convergence of series using various tests,
(g) illustrate the convergence properties of a power series,
(h) determine the limit point of a series of functions,
(i) illustrate the effect of uniform convergence on the limit function with respect to continuity, differentiability, and integrability.
(j) find the Fourier series expansion of different functions using Dirichlet's condition.

2.8 Core Course 8: Multivariate Calculus

On completion of the course, a student should be able to
(a) learn about the basic principles of multi-variable calculus with proofs,
(b) have full knowledge of calculus involving the fundamental tools such as continuity and differentiability,
(c) reason rigorously in mathematical arguments and write their own proofs,
(d) know relationship between the increasing and decreasing behaviour of a function f and the sign of f',
(e) acquire the basic knowledge of vector differentiation and vector integration,
(f) determine and apply, the important quantities associated with scalar fields, such as partial derivatives of all orders, the gradient vector and directional derivative,
(g) determine and apply, the important quantities associated with vector fields such as the divergence, curl, and scalar potential,
(h) calculate line integrals along piecewise smooth paths; interpret such quantities as work done by a force,
(i) calculate double, triple integrals and use it to find volumes,
(j) evaluate line, surface, double and triple integrals and use these integrals to verify the seminal integral theorems (Green's theorem in the plane, Gauss's divergence theorem and Stokes' theorem),
(k) apply vector algebra techniques to analyse problems involving two and three dimensional entities such as lines, curves, planes and surfaces,
(l) use Green's theorem to evaluate line integrals along simple closed contours on the plane,
(m) compute the curl and the divergence of vector fields,

(n) employ the techniques of the higher dimensional differential calculus in problems of physical interests,
(o) compute the area of parametric surfaces in 3-dimensional space,
(p) apply Stokes' theorem to compute line integrals along the boundary of a surface and to give a physical interpretation of the curl of a vector field,
(q) use the divergence theorem to give a physical interpretation of the divergence of a vector function.

2.9 Core Course 9: Ring Theory and Linear Algebra – I

On completion of the course, a student should be able to

(a) describe the characteristics of rings, quotient rings and ideals with examples,
(b) distinguish between ring ideals and quotient rings and also their properties,
(c) familiarize with rings, integral domains, fields,
(d) familiarize with the concepts of ideals and factor rings and homomorphisms and factor rings,
(e) recognize the concepts of the terms span, linear independence, basis, dimension, and apply these concepts to various vector spaces and subspaces,
(f) analyse vectors in $\mathbb{R}^n$ geometrically and algebraically,
(g) analyse finite and infinite dimensional vector spaces and subspaces over a field and their properties, including the basis structure of vector spaces,
(h) use matrix algebra and the relate matrices to linear transformations,
(i) understand the concept of linear transformations and their properties,
(j) use the definition and properties of linear transformations and matrices of linear transformations and change of basis, including kernel, range and isomorphism,
(k) familiarize with transition matrices,
(l) determine the kernel and nullity of of linear transformations.

2.10 Core Course 10: Metric Spaces and Complex Analysis

On completion of the course, a student should be able to

(a) define different kind of compactness, connectedness and their properties,
(b) describe homeomorphism, fixed point and relevant theorems,
(c) introduce elementary complex functions,
(d) find all integral roots and all logarithms of non-zero complex numbers,
(e) evaluate exponentials and integral powers of complex numbers,
(f) define and analyse limits and continuity for complex functions as well as consequences of continuity,
(g) determine whether a given function is differentiable, and if so find its derivative,
(h) use differentiation rules to compute derivatives,
(i) conceive the concepts of analytic functions and be familiar with the elementary complex functions and their properties,
(j) apply the concept and consequences of analyticity and the Cauchy-Riemann equations and of results on harmonic and entire functions including the fundamental theorem of algebra,
(k) use anti derivatives to compute line integrals,
(l) understand the basic methods and techniques of complex integration and its application in contour integration,
(m) find parametrisations of curves, and compute complex line integrals directly,
(n) evaluate integrals along a path in the complex plane and understand the statement of Cauchy's Theorem,
(o) use Cauchys integral theorem and formula to compute line integrals,
(p) evaluate complex contour integrals directly and by the fundamental theorem and applying he Cauchy integral formula,
(q) express complex-differentiable functions as power series,
(r) analyse sequences and series of analytic functions and types of convergence,
(s) identify the isolated singularities of a function and determine whether they are removable, poles, or essential,

(t) compute Laurent series at an isolated singularity, and determine the residue Apply the theory into application of the power series expansions of analytic functions,
(u) represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem,
(v) understand uses of improper integrals in various situations.

2.11 Core Course 11: Group Theory – II

On completion of the course, a student should be able to
(a) develop idea about automorphisms,
(b) understand inner automorphisms and their properties,
(c) extend group structure to finite permutation groups (Cayley's Theorem),
(d) understand Sylow's Theorems,
(e) generate groups given specific conditions,
(f) investigate symmetry using group theory,
(g) find conjugacy classes of S_n.

2.12 Core Course 12: Numerical Methods

On completion of the course, a student should be able to
(a) obtain numerical solutions of algebraic and transcendental equations,
(b) learn about various interpolating and extrapolating methods,
(c) solve initial and boundary value problems in differential equations using numerical methods,
(d) apply various numerical methods in real life problems,
(e) work out numerical differentiations and integrations whenever and wherever routine methods are not applicable,
(f) demonstrate an understanding of the fundamental principles of digital computing, including number representation and arithmetic operations,
(g) develop and implement stable and accurate numerical methods to solve linear systems of equations and find roots of linear and non-linear equations and check the accuracy of the solutions,
(h) perform numerical interpolation, curve fitting, integration, and differentiation,
(i) develop and implement stable algorithms to solve ordinary differential equations and simple partial differential equations.

2.13 Core Course 13: Ring Theory and Linear Algebra – II

On completion of the course, a student should be able to
(a) define polynomial rings and commutative rings,
(b) acquire the concept of principal ideal domain, Euclidean domain and unique factorisation domain and their relationships,
(c) check whether a polynomial is irreducible or not over a certain field using Eisenstein's criterion,
(d) acquire the concept of Dual basis and find the connections between dual basis and linear transformations,
(e) develop the concept of minimal polynomial,
(f) describe Cayley-Hamilton theorem and use it to find inverse of a matrix,
(g) develop an idea about inner product vector space,
(h) use inner product space to proceed for normed linear spaces,
(i) use Gram-Schmidt process to find orthogonal set of non-null vectors from any arbitrary set of vectors.

2.14 Core Course 14: Partial Differential Equations and Applications

On completion of the course, a student should be able to
(a) describe the origin of partial differential equation and distinguish the integrals of first order linear partial differential equation into complete, general and singular integrals,
(b) familiarise with the various techniques of finding the solution of the differential equations,
(c) acquire the idea of Lagrange's method for solving the first order linear PDEs,

(d) recognize the major classification of PDEs and the qualitative differences between the classes of equations,
(e) be competent in solving linear PDEs using classical solution methods,
(f) be familiar with the modelling assumptions and derivations that lead to PDEs,
(g) recognize the major classification of PDEs and the qualitative differences between the classes of equations,
(h) be competent in solving linear PDEs using classical solution methods,
(i) classify PDEs and transform into canonical forms,
(j) solve linear PDEs of both first and second order,
(k) apply partial derivative equation techniques to predict the behaviour of certain phenomena,
(l) apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialization,
(m) extract information from partial derivative models in order to interpret reality,
(n) identify real phenomena as models of PDEs.

2.15 Discipline Specific Elective 1A: Probability and Statistics

On completion of the course, a student should be able to
(a) understand of exploratory data analysis,
(b) able to write a short-report describing a simple statistical data set,
(c) understand elementary probability theory and its applications,
(d) understand the laws of probability and the use of Bayes' theorem,
(e) understand the concept of a statistical distribution,
(f) understand the standard univariate distributions and their properties,
(g) understand the Central Limit Theorem and its applications,
(h) understand the basic concepts of statistical inference.

2.16 Discipline Specific Elective 1B: Linear Programming

On completion of the course, a student should be able to
(a) define a LPP in standard form and Canonical form,
(b) identify a feasible solution, a basic feasible solution and an optimal solution using simplex method,
(c) formulate and model a linear programming problem from a word problem and solve them graphically in 2 and 3 dimensions, while employing some convex analysis,
(d) place a Primal LPP into standard form and use the Simplex Method or The Big M Method to solve it,
(e) formulate and solve a number of classical linear programming problems and such as the minimum spanning tree problem, the assignment problem, (deterministic) dynamic programming problem, the transportation problem, the maximal flow problem, or the shortest-path problem, while taking advantage of the special structures of certain problems. Use dual simplex method to find optimal solutions,
(f) understand duality theorems and dual simplex method: to identify the advantages of duality method,
(g) apply the theorems on duality to problems appropriately,
(h) use dual simplex method to find optimal solutions,
(i) find the dual and identify and interpret the solution of the dual Problem from the final tableau of the primal problem,
(j) explain the concept of complementary slackness and its role in solving primal/dual problem pairs,
(k) be able to modify a primal Problem and use the fundamental insight of Linear Programming to identify the new solution, or use the dual simplex method to restore feasibility,
(l) acquire the knowledge of transportation and assignment problems,
(m) understand various methods of solving transportation and assignment problems,
(n) explain the transportation Problem and formulate it as an LPP and hence solve the problem,
(o) determine that an assignment Problem is a special case of LPP and hence solve by Hungarian method.

2.17 Discipline Specific Elective 2A: Number Theory

On completion of the course, a student should be able to

(a) find quotients and remainders from integer division,
(b) apply Euclid's algorithm and backwards substitution,
(c) understand the definitions of congruences, residue classes and least residues,
(d) add and subtract integers modulo n, multiply integers and calculate powers modulo n,
(e) determine multiplicative inverses modulo n and use to solve linear congruences,
(f) understand various types of numbers and their properties,
(g) acquire the basic knowledge of Number Theory,
(h) apply the knowledge of Number Theoretic problems in practical situations.

2.18 Discipline Specific Elective 2B: Mechanics

On completion of the course, a student should be able to

(a) construct free-body diagrams and to calculate the reactions necessary to ensure static equilibrium,
(b) understand the analysis of distributed loads,
(c) have knowledge of internal forces and moments,
(d) calculate centroids and moments of inertia,
(e) know concepts of relative motion, inertial and non-inertial reference frames,
(f) handle parameters defining the motion of mechanical systems and their degrees of freedom,
(g) do the study of the interaction of forces between solids in mechanical systems,
(h) calculate centre of mass and inertia tensor of mechanical systems,
(i) apply the vector theorems of mechanics and interpret their results,
(j) know Newton's laws of motion and conservation principles,
(k) have the introduction to analytical mechanics as a systematic tool for problem solving.

2.19 Discipline Specific Elective 3A: Point Set Topology

On completion of the course, a student should be able to

(a) understand terms, definitions and theorems related to Topology,
(b) demonstrate knowledge and understanding of concepts such as open and closed sets, interior, closure and boundary,
(c) create new topological spaces by using subspace, product and quotient topologies,
(d) use continuous functions and homeomorphisms to understand the structure of a topological space,
(e) apply theoretical concepts in Topology to understand real world applications,
(f) know separation axioms, countability axioms and Urysohn's metrisation theorem,
(g) know function spaces, pointwise and uniform convergence,
(h) develop an idea about connectedness, path-connectedness and limit point compactness.

2.20 Discipline Specific Elective 3B: Boolean Algebra and Automata Theory

On completion of the course, a student should be able to

(a) distinguish different number systems,
(b) explain conversion of one number system to another,
(c) performs binary arithmetic operations,
(d) identify various methods for representing characters in a computer,
(e) explain the concept of Boolean Algebra,
(f) explain logical operators and logic gates,
(g) design circuits for simple Boolean expressions,
(h) implement basic logic gates using universal gates,
(i) define Automata,
(j) discuss the acceptability of a string by finite automation,
(k) construct non-deterministic finite state machine.

2.21 Discipline Specific Elective 4A: Differential Geometry

On completion of the course, a student should be able to

(a) define and analyse the equivalence of two curves,
(b) find the derivative map of an isometry,
(c) defines surfaces and their properties,
(d) define parametrization of surfaces,
(e) express tangent spaces of surfaces,
(f) explain differential maps between surfaces and find derivatives of such maps,
(g) integrate differential forms on surfaces,
(h) compute quantities of geometric interest such as curvature, as well as develop a facility to compute in various specialized systems, such as semi geodesic coordinates or ones representing asymptotic lines or principal curvatures,
(i) list topological aspects of surfaces,
(j) define the concept of manifolds,
(k) give examples of manifolds and investigate their properties.

2.22 Discipline Specific Elective 4B: Theory of Equations

On completion of the course, a student should be able to

(a) describe the graphical representation of a polynomial, maximum and minimum values of a polynomial,
(b) acquire the concept of symmetric functions,
(c) use Newton's theorem to find the sums of power of roots, homogeneous products, limits of the roots of equation,
(d) derive Sturm's theorem and its application.

References

[1] "Learning Outcomes based Curriculum Framework (LOCF), B.A./B.Sc. (Hons) Mathematics & B.A./B.Sc. with Mathematics as a subject", University Grants Commission, New Delhi, 2019, URL: https://www.ugc.ac.in/pdfnews/4540979_LOCF-Final_Mathematics-report.pdf.