Hiralal Bhakat College

Nalhati, Birbhum

Details of

Program Outcomes (POs), Program Specific Outcomes (PSOs) and Course Outcomes (COs)

Department: Mathematics

Program Name: 3-year UG Programme in Mathematics under CCFUP as per NEP 2020 of BU

Objectives

• To impart teaching so that the students could develop higher-order thinking capacities about the fundamental aspects of mathematics.
• To train the students with mathematical knowledge and computational techniques so that they can deal with the problems faced in different walks of life.
• To impart sophisticated mathematical skills so that students can undertake self employment initiatives.
• To make the students capable of pursuing research work in various emerging fields of mathematics and its applications.

Program Outcomes (POs)

PO1: Development of critical thinking for solving complex problems.

PO2: Skills to characterise problems, formulate a hypothesis, evaluate and validate outcomes, and draw reasonable conclusions thereof.

PO3: Development of the effective scientific and technical communications in both oral and written forms.

Program Specific Outcomes (PSOs)

PSO1: Understanding the fundamental axioms in mathematics, and capability of developing ideas based on them.

PSO2: Development of mathematical reasoning and an understanding of the underlying fundamental structures of mathematics (i.e., sets, relations and functions, logical structure), and the relationship among them.

PSO3: Motivation for research studies in mathematics and related fields with real life applications.

PSO4: Knowledge in a wide range of mathematical techniques and applications of mathematical methods/tools in other scientific and engineering domains.

PSO5: Nurturing problem-solving skills, thinking, creativity through assignments, tutorials.

PSO6: Application of knowledge in practical filed and real life.

PSO7: Preparing for various competitive examinations at the national and international levels.

Course Outcomes (COs)

Semester	Course Type	Course Title & Code	Course Outcomes (COs)
1st SEM	**Major-1 & Minor-1**	Calculus, Geometry &Vector Calculus **(MATH1011 & MATH1021)**	Students will be able to • learn about higher order derivatives, Leibnitz rule and its applications • know about differential application, asymptotes, envelop, point of inflections etc. • Study on indeterminate forms, L'Hospital's rule, concavity of curves • Learn on Reduction formulae, derivations and illustrations of reduction formulae for the integration • Find general equation of second-degree, classification of conics, polar equations of conics, spheres, cylindrical surfaces. central conicoid, paraboloids, plane sections of conicoid, generating lines, classification of quadrics. • Study on vector algebra in terms of Triple product of vectors, introduction to vector functions, algebraic operations on vector-valued functions, limits and continuity of vector functions, differentiation and partial differentiation of vector functions, gradient of a scalar function, divergence and curl of vector functions.
	SEC-1	Graph Theory **(MATH1051)**	Students will be able to • Know the definition, examples and basic properties of graphs, complete graphs, Havel-Hakimi theorem (Statement and its application), bi-partite graphs, isomorphism of graphs. • Learn Königsberg bridge problem, Eulerian graph, Hamiltonian graph, Representation of a graph by a matrix, the adjacency matrix, incidence matrix, weighted graph. • Study Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm. • Find Planar and non-planar graphs, Euler's formula, colouring of graphs, four colour problem, five colour theorem.
2nd SEM	**Major-2 & Minor-2**	Introductory Algebra and Number Theory **(MATH2011 &**	Students will be able to • Know about Complex Numbers: De Moivre's theorem for rational indices and its applications. • Learn Theory of equations: Fundamental Theorem

		MATH2021)	of Algebra (Statement), Relation between roots and coefficients, Transformation of equation, Descarte's rule of signs, Cubic and biquadratic equations, Reciprocal equation, separation of the roots of equations, Strum's theorem. Inequality: The inequality involving AM≥GM≥HM, Cauchy-Schwartz inequality. • Learn on Partial order, total order relations, partitions of a set and its connection with equivalence relation, greatest lower bound, least upper bound, maximal, minimal elements, lattice, bounded lattice, modular lattice, distributive lattice, complemented lattice, statement of Zorn's lemma. • Study on Semigroups, Monoids, Groups – examples including permutation group, Matrix groups ($Mn\times n(\mathbb{R})$,$GLn(\mathbb{R})$,$SLn(\mathbb{R})$), Zn, elementary properties of groups, generators and relations, order of an element of a group, Subgroups and examples of subgroups, cosets, normal subgroup, center of a group, cyclic groups, Lagrange's theorem, Rings, subrings, Ideals (left, right and two sided), integral domain, field, subfield – examples and basic properties, characteristic of a ring and field. • Learn on Well ordering principle of set of natural numbers, pigeon-hole principle, division algorithm, greatest common divisor (gcd), Euclidean algorithm, least common multiple (lcm), Linear Diophantine equation, prime numbers, relatively prime numbers and related properties including Euclid's lemma, fundamental theorem of arithmetic and its applications, perfect square and square free integers, congruences, solution of congruences, Binary and decimal representation of integer, Chinese remainder theorem and its application. Fermat's little theorem, Wilson's theorem, sum of two squares, Arithmetic function-$\phi(n)$, $d(n)$,$\sigma(n)$.
	SEC-2	Programming in C **(MATH2051)**	Students will be able to • Know the Introduction, basic structures, character set, keywords, identifiers, constants, variable-type declaration, operators: arithmetic, relational, logical, assignment, increment, decrement, conditional. • Learn on Operator precedence and associativity, arithmetic expression, evaluation and type conversion, character reading and writing, formatted input and output statements. • Take Decision making (branching and looping): Simple and nested if, if – else, switch, while, do-while, for statements. • Know the Concept of array variables, string handling with arrays – reading and writing, string

			handling functions. • User defined functions, call-by-value, call-by-reference functions and their uses, return values and their types, nesting of functions, recursion. • Structures: Declaration, initialization, nested structures, array of structures, array within structures. • Pointers: Declaration, initialization, accessing variables through pointer, pointer arithmetic, pointers and arrays.
3rd SEM	**Major-3**	Real Analysis I **(MATH3011)**	Students will be able to • Learn on Review of algebraic and order properties of $\mathbb{R}$, idea of countable sets, uncountable sets and uncountability of $\mathbb{R}$. Bounded above sets, bounded below sets, bounded sets, unbounded sets. Supremum and infimum. Completeness property of $\mathbb{R}$ and its equivalents. The Archimedean property, -neighbourhood of aεdense sets in $\mathbb{R}$. Density of rational and irrational numbers in $\mathbb{R}$. Intervals, point in $\mathbb{R}$, interior points of a set, open set, limit point of a set, isolated points, derived set, closed set. Interior, exterior, frontier and boundary of a set. Bolzano – Weierstrass theorem for sets. Compact sets in $\mathbb{R}$, Heine – Borel theorem. • Learn on Sequences of real numbers, bounded and unbounded sequences, convergent sequence, limit of a sequence and related Theorems. Monotonically increasing and decreasing sequences, relevant theorems, subsequences, theorems on monotone subsequence, Bolzano – Weierstrass theorem for sequences. Cauchy sequences, Cauchy's convergence criterion, lim sup, lim inf and associated theorems. • Study on Infinite series of real numbers, convergence and divergence of infinite series, Cauchy's convergence criterion, Abel's – Pringsheim's theorem. Tests for convergence: comparison tests, D' Alembert's ratio test, p- series, Cauchy's root test, Raabe's test, Gauss's test, Logarithmic test, De Morgan and Bertrand test, integral test, Cauchy's condensation test. Alternating series, Leibnitz's test, Absolute and conditional convergence. Riemann's rearrangement theorem (statement only). • Learn about δ-ε Limit of a function (− definition), sequential criteria for limits, divergence criteria, algebra of limits & theorems, infinite limits and limits at infinity. Continuous functions, sequential criteria for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, Bolzano's theorem on continuity,

			intermediate value theorem, fixed point theorem. Uniform continuity, non-uniform continuity criteria, theorems on uniform continuity.
	Major-4	Linear Algebra **(MATH3012)**	Students will be able to • Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces, extension, deletion and replacement theorems. • Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations, transpose of a linear transformation and matrix representation of the transpose of a linear transformation, isomorphisms, isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix. • Study on Elementary operations on matrices, row reduction and echelon forms of a matrix, rank of a matrix, characterization of invertible matrices using rank. Eigenvalues, eigenvectors and characteristic equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix. • Know the System of linear equations, the matrix equation $Ax = b$, necessary and sufficient condition for consistency of a linear non-homogeneous system of equations, solution of systems of linear equations using Gaussian elimination method and matrix inversion method, solution sets of linear systems, applications of linear systems. • Learn the Eigen spaces of a linear operator, diagonalizability, invariant subspaces, the characteristic polynomial and the minimal polynomial of a linear operator, diagonalization, Jordan canonical forms. • Find Bilinear form, matrix associated with a bilinear form, quadratic form, rank, signature and index of a quadratic form, Sylvester's law of inertia (statement only), reduction of a quadratic form to normal form.
	SEC-3	Mathematical Modelling **(MATH3051)**	Students will be able to • Overview of mathematical modelling and its applications in understanding real-world phenomena. Introduction to model classifications (Deterministic, Stochastic, Continuous, Discrete); Linear models and their applications; Usage of linear regression for modelling relationships between variables; Fitting linear models to data in analyzing trends and making predictions; Exponential model and its applications; Usage of

			exponential growth and decay models in population studies, finance, compound interest, half-life, and other relevant fields. • Learn Logistic models and their applications; Usage of logistic growth models in population studies, ecology, and epidemiology; Significance of logistic models in situations where growth is initially rapid but levels off over time. Optimization models and their applications; Use of linear programming and optimization techniques to maximize or minimize objectives; Importance of optimization models in resource allocation, production planning, and decision-making. Probabilistic / Stochastic models and their applications. • Study Time series models and their applications; Importance of time series models in analyzing trends, seasonality, and forecasting future outcomes with applications. Introduction to simulation models and their applications; Monte Carlo simulation model, simulating deterministic features (area under a curve, volume under a surface) and other techniques for modelling uncertainty; Significance of simulation models in evaluating performance, risk analysis, decision support, random number generation.
4^{TH} SEM	**Major-5**	Metric Spaces **(MATH4011)**	Students will be able to • Know Metric spaces: Definition and examples. Open and closed balls, neighbourhood, interior points, open sets, interior of a set. limit points, closed sets, closure of a set, diameter of a set, boundedness of a set, exterior points, frontier points, boundary points, metric subspaces, equivalent metrics. • Learn on Convergence of a sequence , Cauchy sequences, bounded sequences, complete metric spaces, dense sets, nowhere dense sets , sets of first and second category, Baire's category theorem, Cantor's intersection theorem, completion of a metric space, completeness property of $\mathbb{R}n$, $C[a,b]$ with supmetric, lp $(1 \leq p < \infty)$, incompleteness property of $l\infty$ and $C[a,b]$ with integral metric. • Study Limit and continuity of mappings defined on metric spaces, sequential criterion of continuity, uniform continuity, homeomorphism, contraction mapping, Banach's contraction principle and its applications, viz. existence theorem on ODE (Picard's theorem), implicit function theorem. • Learn Separated sets, connected sets, connectedness of a metric space and its properties, connectedness property under continuity, connected

			subsets of $\mathbb{R}$, components and relevant theorems. • Know Open cover, compactness, countable compactness, sequential compactness, B-W compactness property, ϵ net, totally bounded sets, coherence between compactness, completeness and totally boundedness property, Lebesgue number, Lebesgue covering lemma, equivalence of compactness, countable compactness, sequential compactness and B-W compactness property. Finite intersection property, compactness property using finite intersection property, compactness property under continuity and uniform continuity. • Find First and second countability of a metric space, separability and Lindelöf properties of a metric space.
	Major-6	Group Theory & Ring Theory **(MATH4012)**	Students will be able to • Define Group: Homomorphism, isomorphism, endomorphism, automorphism, inner automorphism, quotient group, isomorphism theorems (1st, 2nd and 3rd), correspondence theorem, normalizer of a set, commutator subgroup, characteristic subgroup, maximal normal subgroup, simple group, dihedral group of order n and quaternion group – their properties, classification of all groups upto order 8. • know Action of a group on a set - examples, representation of a group action in terms homomorphism, Cayley's theorem, stabilizer of a point and orbit of a point – their relation, class equation, conjugacy class of an element, Burnside theorem, p-group and its properties (p prime), Cauchy's theorem on finite group, Sylow theorems (1st, 2nd, 3rd) – its application. • Study Direct product, Direct sum – their differences and properties, semi-direct product of two groups, Representation of finite abelian group. • Know Ring: Ring homomorphism, quotient ring, isomorphism theorems (1st, 2nd and 3rd), correspondence theorem, maximal ideal, prime ideal and primary ideal - their existence, relations, properties. • Learn Irreducible and prime elements, Euclidean domain, Principal ideal domain, unique factorization domain – their properties, polynomial rings of one indeterminate over a field F and integral domain, $F[x]$, irreducible criteria of polynomials.
	Major-7	Multivariate Calculus & Tensor Calculus	Students will be able to • Learn Functions of several variables, repeated and double limits and continuity of functions of n

		(MATH4013)	variables. Partial derivatives, Euler's theorem and its converse for functions of three variables, total derivative and differentiability, sufficient condition for differentiability. Chain rules, directional derivatives, Schwarz theorem, Young's theorem, Jacobian, the gradient, maximal and normal property of the gradient, tangent planes. Extrema of functions of n variables, method of Lagrange's undetermined. • Define functions. Iterated or repeated integral, change of order of integration. Triple integral. Cylindrical and spherical coordinates. Change of variables in double integrals and triple integrals. Transformation of double and triple integrals. Determination of volume and surface area by multiple integrals. Differentiation under the integral sign, Leibniz's rule. • Know Historical study of tensor. Concept of En. Tensor as a generalization of vector in $E2$,$E3$ and En. Einstein's Summation convention. Kronecker delta. Algebra of tensor: Invariant, contravariant and covariant vectors. Contravariant, covariant and mixed tensors. Symmetric and skew-symmetric tensors. Addition, subtraction and scalar multiplication of tensors. Outer product, inner product and contraction. Quotient law. • Learn Calculus of tensor: Riemannian space. Line element. Metric tensor. Reciprocal metric tensor. Raising and lowering of indices. Associated tensor. Magnitude of vector. Angle between two vectors. Christoffel symbols of different kinds and laws of transformations. Covariant differentiation. Gradient, divergence, curl and Laplacian. Ricci's theorem. Riemann-Christoffel curvature tensor. Ricci tensor. Scalar curvature. Einstein's space (Definition only).
	Minor-3	Ordinary Differential Equations **(MATH4021)**	Students will be able to • Study Picard's existence theorem (statement only) for $dy\ dx = f(x,y)$ with $y = y0, x = x0$. Exact differential equations, condition of integrability. Equation of first order and first degree-exact equations and those reducible to exact form. Equations of first order higher degree-equations solvable for $p = dy\ dx$, equations solvable for y, equations solvable for x, singular solutions, Clairaut's form. Singular solution as envelope to family of general solution to the equation. • Learn Linear differential equations of second and higher order. Two linearly independent solutions of second order linear differential equation and Wronskian, general solution of second order linear

			differential equation, solution of linear differential equation of second order with constant coefficients. Particular integral (P.I.) for second order linear differential equation with constant coefficients for polynomial, sine, cosine, exponential functions and for functions as combination of them or involving them. Method of variation of parameters for P.I. of linear differential equation of second order. Homogeneous linear equation of n-th order with constant coefficients. Reduction of order of linear differential equation of second order when one solution is known. • Explain Simultaneous linear ordinary differential equation in two dependent variables. Solution of simultaneous equations of the form $dx\ P = dy\ Q = dz\ R$. Equation of the form (Paffian form) $dx + Qdy + Rdz = 0$. Necessary and sufficient condition for existence of integrals of the above. Qualitative studies of differential equations, Equilibrium points and their classifications, Phase plane analysis, Plotting of phase diagrams for some simple problems.

Mapping of
Program Specific Outcomes (PSOs)
&
Course Outcomes (COs)

CO details	Program Specific Outcomes (PSOs) details						
Course Title	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7
Calculus, Geometry & Vector Calculus	√		√	√		√	
Graph Theory	√	√		√	√		√
Introductory Algebra & Number Theory	√	√	√	√		√	√
Logic and sets	√		√		√		√
Programming in C	√	√		√		√	√
Real Analysis I	√		√	√	√	√	
Linear Algebra	√	√	√		√		√
Mathematical Modelling	√	√		√		√	
Metric Spaces	√		√		√		√
Group Theory & Ring Theory	√	√		√	√		√
Multivariate Calculus & Tensor Calculus	√	√	√		√	√	
Ordinary Differential Equations	√		√		√		√

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