Module for B.Sc. Mathematics Honours

Academic Year 2019 – 2020

1. Module for Semester – I (New CBCS Syllabus under Bankura University):

Name of the Teacher	Duration	Course
Dr. SamiranKarmakar	July – September, 2019	**<u>Core– I (Calculus, Geometry, Differential Equation)</u>** *Unit – I*: Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, concavity and inflection points, envelopes, asymptotes. [12L]
	October – December, 2019	curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L' Hospital's rule, applications in business, economics and life sciences. [8L]
Sri Uttam Kr. Mahanty	July – September, 2019	*Unit II:* Reduction formulae, derivations and illustrations of reduction formulae of the type $f\sin nx dx$, $f\cos nx\,dx$, $f\tan nx\,dx$, $f\sec nx\,dx$, $f(\log x)^n dx$, $f\sin nx\sin mx\,dx$, parametric equations, parameterizing a curve. [12L]
	October – December, 2019	Arc length, arc length of parametric curves, area of surface of revolution. Techniques of sketching conics. [8L]
Ms. Mridula Sarkar	July – September, 2019	*Unit III*: Reflection properties of conics, rotation of axes and second-degree equations, classification of conics using the discriminant, polar equations of conics. Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, Generating lines, classification of quadrics, Illustrations of graphing standard quadric surfaces like cone, ellipsoid. [6L]
	October – December, 2019	*Unit IV* Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations. [4L]
Sri UtpalBadyakar	July – September, 2019	**<u>Core – II (Algebra)</u>** *Unit I:* Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.

		Theory of equations: Relation between roots and coefficients, Transformation of equation, Descartes rule of signs, Cubic and biquadratic equation. Inequality: The inequality involving AM≥GM≥HM, Cauchy-Schwartz inequality. [12L]
	October – December, 2019	Equivalence relations. Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic. [8L]
Dr. Swapan Mukhopadhyay	July – September, 2019	*Unit III* Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence. [8L]
	October – December, 2019	Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of Rn, dimension of subspaces of Rn, rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix. [5L]

2. Module for Semester – II (New CBCS Syllabus under Bankura University):

Name of the Teacher	Duration	Course
Dr. SamiranKarmakar	January – March, 2020	**<u>Core– III (Real Analysis)</u>** *Unit – I*: Review of Algebraic and Order Properties of R, ε-neighbourhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets. Suprema and Infima. Completeness Property of R and its equivalent properties. [12L]
	April – June, 2020	The Archimedean Property, Density of Rational (and Irrational) numbers in R, Intervals. Limit points of a set, Isolated points, Open set, closed set, derived set, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem. [8L]
Sri UtpalBadyakar	January – March, 2020	*Unit II:* Sequences, Bounded sequence, Convergent sequence, Limit of a sequence, lim inf, lim sup. Limit Theorems. Monotone Sequences,

		Monotone Convergence Theorem. Subsequences, Divergence Criteria. Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion. [12L]
	April – June, 2020	*Unit III* Infinite series, convergence and divergence of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Integral test. Alternating series, Leibniz test. Absolute and Conditional convergence. [8L]
Dr. Mridula Sarkar	January – March, 2020	**<u>Core – IV (Differential Equations and Vector Calculus)</u>** *Unit I:* Lipschitz condition and Picard's Theorem (Statement only). General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters. *Unit II* Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients. Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions. [12L]
	April – June, 2020	*Unit II* Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions. *Unit III* Equilibrium points, Interpretation of the phase plane. Power series solution of a differential equation about an ordinary point, solution about a regular singular point. [15L]
Mr. Uttam Kr. Mahanty	January – March, 2020	*Unit IV* Triple product, introduction to vector functions, operations with vector-valued functions.
	April – June, 2020	limits and continuity of vector functions, differentiation and integration of vector functions.

3. Module for Semester – III (New CBCS Syllabus under Bankura University):

Name of the Teacher	Duration	Course
Dr. Swapan Mukhopadhyay	July – September, 2019	**<u>CoreV (</u>Theory of Real Functions & Introduction to Metric Space)** *Unit – I*:

		Limits of functions (ε - δ approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem. *Unit II*: Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials [12L]
	October – December, 2019	*Unit III* Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, $\ln(1 + x)$, $1/ax+b$ and $(1 +x)^n$. Application of Taylor's theorem to inequalities. *Unit IV* Metric spaces: Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, subspaces, dense sets, separable spaces. [8L]
Sri UtpalBadyakar	July – September, 2019	**CoreVI (Group Theory I)** *Unit – I*: Symmetries of a square, Dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups. *Unit II*: Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups. [12L]
	October – December, 2019	*Unit - III* Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem. *Unit IV* External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups. *Unit V* Group homomorphisms, properties of homomorphisms, Cayley's

		theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.
Ms. Mridula Sarkar	July – September, 2019	**Core VII (Numerical Models)** *Unit I*: Algorithms. Convergence. Errors: Relative, Absolute. Round off. Truncation. *Unit II*: Transcendental and Polynomial equations: Bisection method, Newton's method, Secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods. *Unit III*: System of linear algebraic equations: Gaussian Elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method and their convergence analysis. LU Decomposition. *Unit IV* Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations; methods based on finite differences. [6L]
	October – December, 2019	*Unit V* Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule, Simpsons 3/8th rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite Trapezoidal rule, Composite Simpson's 1/3rd rule, Gauss quadrature formula. The algebraic eigenvalue problem: Power method. Approximation: Least square polynomial approximation. *Unit VI* Ordinary Differential Equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four. [4L]
Dr. SamiranKarmakar	July – September, 2019	**SEC - I (C Programming)** *Unit I:* Programming paradigms, characteristics of object-oriented programming languages, brief history of C, structure of C program, differences between C and C++, basic C operators, Comments, working with variables, enumeration, arrays and pointer. [12L]

	October – December, 2019	*Unit II* Objects, classes, constructor and destructors, friend function, inline function, encapsulation, data abstraction, inheritance, polymorphism, dynamic binding, operator overloading, method overloading, overloading arithmetic operator and comparison operators. *Unit III* Template class in C, copy constructor, subscript and function call operator, concept of namespace and exception handling.

Module for ***Computer Aided Numerical Methods –Practical:***

Students are divided into two groups and three teachers are allotted for these groups:

I) Group A: Dr. SamiranKarmakar
II) Group B: Dr. Mridula Sarkar

August – September, 2019	Prerequisites: PC – operating system, Basics of C Compiler Dev C++, Compilation, Run Commends. 1. Calculate the sum 1/1 + 1/2 + 1/3 + 1/4 + ----------+ 1/ N. 2. Enter 100 integers into an array and sort them in an ascending order. 3. Finding a real Root of an equation byNewton-Rapson's method.
October – December, 2019	5. Interpolation (Taking at least six points) by Lagrange's formula 6. Integration by (i) Trapezoidal rule (ii) Simpson's 1/3rd rule (taking at least 10 sub-intervals) 7. Solution of a 1st order ordinary differential equation by fourth-order R. K. Method, taking at least four steps. [30L]

Module for Semester – IV (New CBCS Syllabus under Bankura University):

Name of the Teacher	Duration	Course
Dr. Swapan Mukhopadhyay	January – March, 2020	**Core – VIII (Riemann Integration and Series of Functions)** *Unit – I*: Riemann integration: inequalities of upper and lower sums, Darbaux integration, Darbaux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two Definitions. Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals. Fundamental theorem of Integral Calculus. *Unit – II*:

		Improper integrals. Convergence of Beta and Gamma functions. *Unit – III*: Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test. [12L]
	April – June, 2020	*Unit IV* Fourier series: Definition of Fourier coefficients and series, Reimann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition. Examples of Fourier expansions and summation results for series. *Unit V* Power series, radius of convergence, Cauchy Hadamard Theorem. Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem. [8L]
Dr. SamiranKarmakar	January – March, 2020	**Core – IX (Multivariate Calculus)** *Unit – I*: Functions of several variables, limit and continuity of functions of two or more variables, Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems *Unit – II*: Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals. [12L]
	April – June, 2020	*Unit III* Definition of vector field, divergence and curl. Line integrals, Applications of line integrals: Mass and Work. Fundamental theorem for line integrals, conservative vector fields, independence of path. *Unit IV* Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem. [8L]
Mr. UtpalBadyakar	January – March, 2020	**<u>Core – X (</u>Ring Theory and Linear Algebra 1<u>)</u>** *Unit I:*

		Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals. [12L]
	April – June, 2020	*Unit II:* Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients.
Dr. Mridula Sarkar	January – March, 2019	*Unit III:* Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces [8L]
	April – June, 2018	*Unit IV:* Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.
Mr. UtpalBadyakar	January – March, 2019	**SEC - II (Graph Theory)** *Unit I:* Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bi‑partite graphs isomorphism of graphs. *Unit II:* Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles, theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph, [12L]
	April – June, 2019	*Unit II:* Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm.

4. Module for Semester – V (New CBCS Syllabus under Bankura University):

Name of the Teacher	Duration	Course
Dr. SamiranKarmakar	July – September, 2019	**Core XI (Partial Differential Equations and Applications)** *Unit – I*: Partial Differential Equations – Basic concepts and Definitions. Mathematical Problems. First- Order Equations: Classification, Construction and Geometrical Interpretation. Method of Characteristics for obtaining General Solution of Quasi Linear Equations. Canonical Forms of First-order Linear Equations. Method of Separation of Variables for solving first order partial differential equations. *Unit II*: Derivation of Heat equation, Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order Linear Equations to canonical

		forms. [12L]
	October – December, 2019	*Unit III* The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial Boundary Value Problems. Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end. Equations with non-homogeneous boundary conditions. Non-Homogeneous Wave Equation. Method of separation of variables, Solving the Vibrating String Problem. Solving the Heat Conduction problem *Unit IV* Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law. [8L]
Sri UtpalBadyakar	July – September, 2019	**Core XII (Group Theory II)** *Unit – I*: Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties. *Unit II*: Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finite abelian groups. [12L]
	October – December, 2019	*Unit - III* Group actions, stabilizers and kernels, permutation representation associated with a given group action. Applications of group actions. Generalized Cayley's theorem. Index theorem. *Unit IV* Groups acting on themselves by conjugation, class equation and consequences, conjugacy in Sn, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of An for $n \geq 5$, non-simplicity tests.
Ms. Mridula Sarkar	July – September, 2019	**DSE 1 (Linear Programming)** *Unit I*: Introduction to linear programming problem. Theory of simplex method, graphical solution, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method. Big-M method and their comparison. *Unit II*: Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual. Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem.

		[6L]
	October – December, 2019	*Unit II* assignment problem and its mathematical formulation, Hungarian method for solving assignment problem. *Unit IV* Game theory: formulation of two-person zero sum games, solving two-person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games. [4L]
Dr. Swapan Mukhopadhyay	July – September, 2019	**DSE 2 (Probability and Statistics)** *Unit I:* Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential. *Unit II:* Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables. [12L]
	October – December, 2019	*Unit III* Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central Limit theorem for independent and identically distributed random variables with finite variance, Markov Chains, Chapman-Kolmogorov equations, classification of states. *Unit III* Random Samples, Sampling Distributions, Estimation of parameters, Testing of hypothesis.

5. Module for Semester – VI (New CBCS Syllabus under Bankura University):

Name of the Teacher	Duration	Course
Dr. Swapan Mukhopadhyay	January – March, 2020	**Core XIII (Metric Spaces and Complex Analysis)** *Unit – I*: Metric spaces: Sequences in metric spaces, Cauchy sequences. Complete Metric Spaces, Cantor's theorem. *Unit II*:

		Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of R. [12L]
	April – June, 2020	*Unit II* Homeomorphism. Contraction mappings. Banach Fixed point Theorem and its application to ordinary differential equation. Compactness: Sequential compactness, Heine-Borel property, Totally bounded spaces, finite intersection property, and continuous functions on compact sets. [8L]
Sri SamiranKarmakar	January – March, 2020	*Unit – III*: Limits, Limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability. *Unit IV*: Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy- Goursat theorem, Cauchy integral formula. [12L]
	April – June, 2020	*Unit - V* Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples. *Unit VI* Laurent series and its examples, absolute and uniform convergence of power series.
Dr. Swapan Mukhopadhyay	January – March, 2020	**Core XIV (Ring Theory and Linear Algebra II)** *Unit I*: Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests. [6L]
	April – June, 2020	*Unit I* Eisenstein criterion, and unique factorization in Z [x]. Divisibility in integral domains, irreducible, primes, unique factorization domains, Euclidean domains. [4L]
Ms. Mridula Sarkar	January – March, 2020	*Unit II:* Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and

		Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms. [12L]
	April – June, 2020	*Unit III* Inner product spaces and norms, Gram-Schmidt orthogonalization process, orthogonal complements, Bessel's inequality, the adjoint of a linear operator. Least Squares Approximation, minimal solutions to systems of linear equations. Normal and self-adjoint operators. Orthogonal projections and Spectral theorem.
Mr. UtpalBadyakar	January – March, 2020	**DSE 3 (Number Theory)** *Unit I:* Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson's theorem. *Unit II:* Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues. some properties of Euler's phi-function. [12L]
	April – June, 2020	*Unit III* Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation $x^2 + y^2 = z^2$, Fermat's Last theorem.

Module for ***DSE 4: Project Work –Students of Semester 6 are divided into four groups and they perform their project work under the guideship of any one faculty member according to group division.***