COURSE & PROGRAM OUTCOMES
OF
MATHEMATICS (B.SC.) CBCS
Session: 2022-23

PROGRAMME OUTCOME	Formulate and develop mathematical arguments in a logical manner. Also when there is a need for information, the student will be able to identify, locate, evaluate, and effectively use than information for handling issues or solving problems at hand. Acquire good knowledge and understanding in advanced areas of mathematics and its applications. More specifically- • Enabling students to develop a positive attitude towards mathematics as an interesting and valuable subject of study. • A student should get a relational understanding of mathematical concepts and concerned structures, and should be able to follow the patterns involved, mathematical reasoning. • Ability to analyse a problem, identify and define the computing requirements, which may be appropriate to its solution. • Introduction to various courses like group theory, ring theory, field theory, metric spaces, number theory. • Enhancing students' overall development and to equip them with mathematical modelling abilities, problem solving skills, creative talent and power of communication necessary for various kinds of employment. • Ability to pursue advanced studies and research in pure and applied mathematical science.
PROGRAMME SPECIFIC OUTCOME	Students will be able to apply critical thinking skills to solve problems that can be modelled mathematically, to critically interpret numerical and graphical data, to read and construct mathematical arguments and proofs, to use computer technology appropriately to solve problems and to promote understanding, to apply mathematical knowledge to a career related to mathematical sciences thus cultivating a proper attitude for higher learning in mathematics. Students will be able to • Think in a critical manner. • Know when there is a need for information, to be able to identify, locate, evaluate, and effectively use that information for the issue or problem at hand.

	• Formulate and develop mathematical arguments in a logical manner. • Acquire good knowledge and understanding in advanced areas of mathematics and statistics, chosen by the student from the given courses. • Understand, formulate and use quantitative models arising in social science, Business and other contexts.
LEARNING OUTCOME	Students will be well equipped to critically analyse a given problem, understand and build a mathematical model to represent the problem, solve the resulting equations and interpret the resulting solution. Students are well prepared for higher studies in their chosen field.
COURSES	**OUTCOMES** (On completion of the courses, the students will be able to understand-)
MATH-H-CC-T-01 **Course title: Calculus & Analytical Geometry** After the completion of this course the students will be able to conceptualize the basic concepts about calculus and 2D, 3D Geometry.	● Hyperbolic functions and its derivative, higher order derivatives, Leibnitz rule and its applications. ● Pedal equations. ● Curvature, radius of curvature, centre of curvature, circle of curvature ● Asymptotes. ● Singular points, concavity and inflection points. ● Curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves. ● L'Hospital's rule, applications in business, economics and life sciences. ● Reduction formulae, derivations and illustrations of reduction formulae of different type. ● Parametric equations, parameterizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics.

	● Transformation of coordinate axes, pair of straight lines, reflection properties of conics, canonical form second degree equations, classification of conics using the discriminant, polar equations of conics. ● Straight lines in 3D, sphere, cylindrical surfaces. central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.
Course: MATH-H-CC-T-02 **Course title: Algebra** This course is designed to make students aware of knowledge of Classical Algebra which will be useful in solving real life problems. Also they will acquire knowledge about abstract concepts like Group Theory.	● Polar representation of complex numbers, *n*-th roots of unity, De Moivre's theorem for rational indices and its applications. Direct and inverse circular form of trigonometric and hyperbolic functions. Exponential & Logarithm of a complex number. ● Relation between roots and coefficients, transformation of equation, Descartes rule of signs, solution of cubic equation (Cardan's method). ● 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. ● Equivalence relations and partitions. Functions, composition of functions, Invertible functions, one to one correspondence and cardinality of a set. ● Permutations, cycle notation for permutations, even and odd permutations. ● Definition and elementary properties of groups. Symmetries of a square, dihedral groups, quaternion groups (through matrices). Permutation group, alternating group, finite groups. The group of integers under addition modulo n and the group of units under multiplication modulo n. ● Order of an element, order of a group, simple properties.

	● Orthogonal matrix and its properties. Rank of a matrix, inverse of a matrix, characterizations of invertible matrices. Row reduced and echelon forms, Normal form and congruence operations. ● Solutions of systems of linear equations and their applications.
Course: MATH-H-GE-T-01, MATH-G-CC-T-01, MATH-H-GE-T-03 **Course title: Algebra & Analytical Geometry** This particular course is designed for Generic Elective and Programme Courses to provide a vivid understanding of Complex Numbers, basic Linear and Abstract Algebra and Geometry.	● Complex umbers De Moivre's theorem and its applications. Exponential, Sine, Cosine and Logarithm of a complex number. Definition of az. Inverse circular and hyperbolic functions. ● Polynomials: Fundamental theorem of algebra (Statement only). Polynomials with real coefficients, nature of roots of an equation (surd or complex roots occur in pairs). Statement of Descartes rule of signs and its applications. Relation between roots and coefficients, transformations of equations. Cardan's method of solution of a cubic equation. ● Rank of a matrix: Determination of rank either by considering minors or by sweep-out process. Consistency and solution of a system of linear equations with not more than 3 variables by matrix method. ● Equivalence relations and partitions. Functions, composition of functions, invertible functions, one to one correspondence and cardinality of a set ● Definition and elementary properties of groups. Concepts of permutation Group, alternating group, finite groups. The group of integers under addition modulo n. ● Order of an element, order of a group, subgroups and examples of subgroups. ● Transformations of rectangular axes: Translation, rotation and their combinations. Invariants. ● General equation of second degree in x and y: Reduction to canonical forms. Classification of conics. ● Pair of straight lines: Condition that the general equation of 2nd degree may represent two straight lines. Point of intersection of two intersecting straight lines. Angle between two lines. Equation of two lines joining the origin to the points in which a line meets a conic.

	● Polar equation of straight lines and circles, polar equation of a conic refers to a focus as a pole, polar equation of chord joining two points, polar equations of tangents and normals.
Course: MATH-H-CC-T-03 **Course title: Real Analysis** After completion of this course, the students will be able to think about the basic proof techniques and fundamental definitions related to the real number system. They can demonstrate some of the fundamental theorems of analysis. The students will gradually develop Analysis skills in sets, sequences and infinite series of Real Numbers covered by the three respective units. Students will be able to understand the concept of real-valued functions, limit, continuity, and differentiability in detail. They can find expansions of real functions in series forms, a clear-cut idea on sequence and series of functions defined on a set. The students will become conversant with many of the important theorems of Differential Calculus after the completion of this Core Course.	● The natural numbers Peano's axioms. ● Review of algebraic and order properties of Real Numbers. ● Bounded above sets, bounded below sets, bounded sets, unbounded sets. L.U.B. (supremum) and G.L.B. (infimum) of a set and its properties. L.U.B. axiom or order completeness of Real Numbers. ● Idea of countable sets, uncountable sets and uncountability of Real Numbers. . Countability of Rational Numbers . ● The Archimedean property, density of rational (and irrational) numbers in Real Numbers. ● Intervals, ε-neighbourhood of a point in Real Numbers , interior points and open sets, limit points and closed sets, union and intersection of open and closed sets, isolated points, adherent point, derived set, closure of a set, interior of a set. ● Illustrations of Bolzano-Weierstrass theorem for sets. Upper and lower limits of a subset of Real Numbers ● Compact set in Real Numbers ,basic properties of compact sets. Lindelöf covering theorem (statement only). Heine-Borel theorem and its application. Converse of Heine-Borel theorem. ● Sequences, bounded sequence, convergent sequence, limit of a sequence. ● Limit theorems. Sandwich theorem. Nested interval theorem. ● Monotone sequences, monotone convergence theorem. ● Subsequences, divergence criteria. Monotone subsequence theorem (statement only). ● Bolzano Weierstrass theorem for sequences. ● Cauchy sequence, Cauchy's convergence criterion, Cauchy's 1st and 2nd limit theorems.

	● Infinite series, convergence and divergence of infinite series, Cauchy criterion. ● Tests for convergence: comparison test, limit comparison test, ratio test: D'Alembert's ratio test, Raabe's test, Cauchy's root test, Gauss test (Statement only), integral test, Cauchy's condensation test with examples. ● Alternating series, Leibnitz test. Absolute and conditional convergence. .
Course: MATH-H-CC-T-04 **Course title: Differential Equations** On completion of this course, the student will be able to identify the type of a given differential equation and select and apply the appropriate analytical technique for finding the solution. The students will be well conversant with different types of differential equations.	● Differential equations and mathematical models. ● General, particular, explicit, implicit and singular solutions of a differential equation. ● Separable equations and equations reducible to this form. ● Exact differential equations and integrating factors. ● Linear equation and Bernoulli equations, special integrating factors and transformations. ● First order and higher degree differential equations, solvable for x,y and p , Clairaut's Equations general and singular solutions. ● Lipschitz condition and Picard's Theorem (Statement only). ● General solution of homogeneous equation of second order, principle of superposition 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. ● 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. ● Equilibrium points. ● Interpretation of the phase plane. ● Power series solution of a differential equation about an ordinary point, solution about a regular singular point. ● Partial differential equations – Basic concepts and definitions. Mathematical problems. ● First- order equations: classification, construction and geometrical interpretation, Lagrange's method, Charpit's method. ● 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.
Course: MATH-H-GE-T-02, MATH-G-CC-T-02, MATH-H-GE-T-04	● Real-valued functions defined on an interval, limit and Continuity of a function. Algebra of limits. Differentiability of a function.

Course title: Calculus & Differential Equations On Completion of this course the students will be able to: • Explain the relationship between the derivative of a function as a function and the notion of the derivative as the slope of the tangent line to a function at a point. • Compare and contrast the ideas of continuity and differentiability. To inculcate to solve algebraic equations and inequalities involving the sequence root and modulus function. • To able to calculate limits in inderminate forms by a repeated use of L' Hospital rule. • To know the claim rule and use it to find derivatives of composite functions. • To find maxima and minima, critical points and inflection points of functions and to determine the concarity of curves. • To able to evaluate integrals of rational functions by partial fractions. • Distinguish between linear, nonlinear, partial and ordinary differential equations.	● Successive derivative Leibnitz's theorem and its application to problems. ● Partial derivatives. Euler's theorem on homogeneous function of two and three variables. ● Indeterminate Forms L'Hospital's Rule (Statement and Problems only). ● Statement of Rolle's Theorem and its geometrical interpretation. Mean value theorems of Lagrange and Cauchy. Statements of Taylor's and Maclaurin's theorems with Lagrange's and Cauchy's forms of remainders. Taylor's and Maclaurin's infinite series of various functions. ● Application of the principle of maxima and minima for a function of a single variable. ● Reduction formulae, derivations and illustrations of reduction formulae ● First order equations: (i) Exact equations and those reducible to such equations. (ii) Euler's and Bernoulli's equations (Linear). (iii) Clairaut's Equations General and Singular solutions. ● Second order differential equation: (i) Method of variation of parameters, (ii) Method of undetermined coefficients.

• Solve basic application problems described by second order linear differential equations with constant coefficients. • Find power series solutions about ordinary points and singular points. Find the transforms of derivatives and integrals. • Obtain an approximate set of solution function values to a second order boundary value problem using a finite difference equation	
Course: MATH-H-CC-T-05 **Course title: Theory of Real & Vector Functions** In this course students will learn about fundamental concepts of real analysis and vector functions and applications of different vector differential operators on them.	● 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, neighbourhood property. Sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, ● Bolzano's Theorem, intermediate value theorem. Location of roots theorem, preservation of intervals theorem. ● Uniform continuity, non-uniform continuity criteria, uniform continuity theorem. ● Differentiability of a function at a point and in an interval. ● Caratheodory's theorem. ● Algebra of differentiable functions. ● Darboux's theorem. ● Rolle's theorem. ● Lagrange's and Cauchy's mean value theorems. ● Taylor's theorem with Lagrange's and Cauchy's forms of remainder. ● pplication of Taylor's theorem to convex functions.

	● Applications of mean value theorem to inequalities and approximation of polynomials. ● Relative extrema, interior extremum theorem. ● Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions. . ● Application of Taylor's theorem to inequalities. ● Vector products. ● Introduction to vector functions, operations with vector-valued functions. ● Limits and continuity of vector functions. ● Differentiation and integration of vector functions of one variable. ● Gradient, divergence, curl of vector functions.
Course: MATH-H-CC-T-06 **Course title: Group Theory-I** On the completion of this course, the students will understand the basic concepts of Group Theory in Abstract/Modern Algebra.	● Subgroups, examples and properties of subgroups. ● Product of two subgroups. ● Cyclic group, examples and properties of cyclic group. ● Classification of subgroups of cyclic groups. ● Cosets and their properties. ● Lagrange's theorem and consequences including Fermat's little theorem. ● External direct product of a finite number of groups. ● Centre of a group, centralizer, normalizer. ● Normal subgroups. ● Factor groups. ● Cauchy's theorem for finite abelian groups.

	● Group homomorphisms, basic properties of homomorphisms. ● Cayley's theorem. ● Properties of isomorphisms. ● First, second and third isomorphism theorems.
Course: MATH-H-CC-T-07 **Course title: Numerical Methods (Theory) & Numerical Methods Lab** After completion of this course, the students will be able to apply numerical methods to obtain approximate solutions to mathematical problems, solve the nonlinear equations, system of linear equations and interpolation problems using numerical methods, examine the appropriate numerical differentiation and integration methods to solve problems, apply the numerical methods to solve algebraic as well as differential equations.	● Algorithms, convergence, errors, relative, absolute, round-off, truncation errors. ● Interpolation, Lagrange and ewton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Central difference interpolation formula: Stirling and Bessel interpolation ● Numerical differentiation, methods based on interpolations, methods based on finite differences. ● Numerical integration, ewton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule, Simpson's 3/8th rule, Weddle's rule, Boole's rule. Midpoint rule, composite trapezoidal rule, composite Simpson's 1/3rd rule, Gauss quadrature formula. ● Transcendental and polynomial equations, bisection method, ewton's method, secant method, Regula-Falsi method, fixed point iteration, Newton-Raphson method, rate of convergence of these methods. ● System of linear algebraic equations, Gaussian elimination and Gauss Jordan methods, Gauss Jacobi method, Gauss Seidel method and their convergence analysis, LU decomposition ● The algebraic eigenvalue problem, power method. ● Approximation, least square polynomial approximation. ● Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

Course: MATH-H-SEC-T-1A **Course title: Programming in 'C'** For any of the CAS (Computer aided software), students are introduced to Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays. The students become expert in solving different numerical problems (listed below) by using computer programming techniques *of C.*	● Brief historical development. Computer generation. Basic structure and elementary ideas of computer systems, operating systems, hardware and software. ● Positional number systems: Binary, octal, decimal, hexadecimal systems. Binary arithmetic. ● BIT, BYTE, WORD. Coding of data -ASCII, EBCDIC, etc. ● Algorithms and flow chart: Important features, ideas about complexities of algorithms. Application in simple problems. ● Programming language and importance of 'C' programming. ● Constants, variables and data type of 'C'-Program: Character set. Constants and variables data types, expression, assignment statements, declaration. ● Operation and expressions: Arithmetic operators, relational operators, logical operators. ● Decision making and branching: Decision making with if statement, if-else statement, nesting if statement, switch statement, break and continue statement. ● Control statements: While statement, do-while statement, for statement. ● Arrays: One-dimension, two-dimensional and multidimensional arrays, declaration of arrays, initialization of one and multi-dimensional arrays. ● User-defined Functions: Definition of functions, scope of variables, return values and their types, function declaration, function call by value, nesting of functions, passing of arrays to functions, recurrence of function.
Course: MATH-G-CC-T-03 **Course title: Real Analysis** After completing the course students are expected to be able to: Describe the basic difference between the rational and real numbers.	● Review of algebraic and order properties of $\mathbb{R}$. ● Idea of countable sets, uncountable sets and uncountability of $\mathbb{R}$. Countability of $\mathbb{Q}$. ● Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima. ● Completeness property of $\mathbb{R}$ and its equivalent properties. ● The Archimedean property, density of rational (and Irrational) numbers in $\mathbb{R}$, intervals.

Give the difination of concepts related to metric spaces such as continuity , compactness, convergent etc. Give the essence of the proof of bolzanoweistrass theorem the contraction theorem as well as existence of convergent subsequence using equicontinuity. Evaluate the limits of wide class of real sequences. Determine whether or not real series are convergent by comparision with standard series or using the ratio test. Understand and perform simple proofs. Students will be able to demonstrate basic knowledge of key topics in classical real analysis. The course pervious the basic for further studies with in function analysis, topology & function Theory. They will also know about sequence and series and their convergence.	● Intervals, -neighborhood of a point in $\mathbb{R}$, Interior points, Limit points of a set, isolated points, open set, closed set, union and intersection of open and closed sets. derived set, Closure of a set, Interior of a set. ● Bolzano-Weierstrass theorem for sets. ● Sequences, bounded sequence, convergent sequence, Sandwich theorem. ● Cauchy's convergence criterion for sequences. Cauchy's theorem on limits ● Monotone sequences, monotone convergence theorem ● Infinite series, Convergence and divergence of infinite series, Cauchy's criterion. ● Series of positive terms, Geometric Series, p-Series. ● Tests for convergence: comparison test, limit comparison test, ratio test: D'Alembert's ratio test, Raabe's test, Cauchy's root test. ● Alternating series, Leibnitz test (without proof), definition and examples of Absolute and conditional convergence. ● Power series and radius of convergence
Course: MATH-G-SEC-T-1B **Course title: Vector Calculus** Vector calculus motivates the study of vector differentiation and integration in two and three dimensional spaces.It is widely accepted as a prerequisite in various fields of science and engineering. This course intends to solve practical problems wherever applicable.	● Differentiation and partial differentiation of a vector function. Derivative of sum, dot product and cross product of two vectors. ● Gradient, divergence and curl with applications. ● Vector integration: Line, surface and volume integrals. ● Green's theorem (statement only), surface integrals, integrals over parametrically defined surfaces. Stoke's theorem (statement only), divergence theorem (statement only). Applications of Green's, Stoke's and divergence theorems.

Course: MATH-H-CC-T-08 **Course title: Ring Theory & Linear Algebra** After completion of this course, the students will mainly be able to • Develop a concept on Ring Theory of Abstract Algebra in details. • Understand vector spaces over a field and subspaces and apply their Properties. • Understand linear independence and dependence. • Find the basis and dimension of a vector space, and understand the Change of basis. • Compute linear transformations, kernel and range, and inverse linear Transformations, and find matrices of general linear transformations. • Find eigenvalues and eigenvectors of a matrix and of linear Transformation. • The Cayley-Hamilton Theorem and its use in finding the inverse of a matrix • Understand various concepts of Abstract & Linear Algebra.	● Definition and examples of rings. Properties of rings. ● Subrings. ● Integral domains and fields. Characteristics of a ring. ● Ideal, ideal generated by a subset of a ring. ● Factor rings. ● Operations on ideals. ● Prime and maximal ideals. ● Ring homomorphisms, properties of ring homomorphisms. ● Isomorphism theorems I, II and III. ● Field of quotients. ● Concept of Vector space over a field: Examples, concepts of Linear combinations, linear dependence and independence of a finite number of vectors. ● Sub- space, concepts of generators and basis of a finite dimensional vector space. ● Replacement theorem. Extension theorem. Deletion theorem and their applications. ● Row space, column space. ● Euclidean Spaces. Orthogonal and orthonormal vectors. Gram-Schmidt process of orthogonalization. ● Linear transformations. Null space. Range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. ● Eigenvalues, eigen vectors and characteristic equation of a matrix. Matric polynomials, Cayley-Hamilton theorem and its use in finding the inverse of a matrix. ● Diagonalization, Canonical forms.

Course: MATH-H-CC-T-09 **Course title: Multivariate Calculus & Tensor Analysis** After completion of this unit of the course which covers the following topics on multiple integrals, line integrals etc., the student will be able to apply these concepts to solve many real-life problems that may arise in different fields.	● Functions of several variables, limit and continuity of functions of two or more variables. ● Differentiability and total differentiability. Partial differentiation. ● Sufficient condition for differentiability. Schwarz Theorems, Young's Theorems. ● Chain rule for one and two independent parameters. ● Homogeneous function and Euler's theorem on homogeneous functions and its converse. ● Jacobians and functional dependence. ● Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems. ● Double integration over a rectangular region. Double integration over non-rectangular regions. Double integrals in polar coordinates. ● Triple integrals. Triple integral over parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical coordinates. ● Change of variables in double integrals and triple integrals. ● Directional derivatives. The gradient, maximal and normal property of the gradient. ● Line integrals, applications of line integrals: Mass and work. Fundamental theorem for line integrals, conservative vector fields, independence of path. ● Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The divergence theorem. pplications of Green's, Stoke's and divergence theorems. ● A tensor as a generalized concept of a vector and its generalization . Space of –dimension. Transformation of coordinates. Summation convention. ● Definition of scalar or invariant. Contravariant, covariant vectors and tensors, mixed tensors of arbitrary order. Kronecker delta. ● Equality of tensors, addition, subtraction of two tensors.

	● Outer product of tensors, contraction and inner product of tensors. ● Symmetric and skew symmetric tensors. ● Quotient law, reciprocal tensor of a tensor. ● Metric tensor, Christoffel symbol, covariant derivative.
Course: MATH-H-CC-T-10 **Course title: Linear Programming Problems & Game Theory** The objective of this course is to study basic theory of Linear Programming, Integer Programming and Two-Person Zero-Sum Games with economic applications. The emphasis is on the formulation of the mathematical model, and also on the methods for solving linear and integer programming problems. Students will get knowledge on the basic theory and some models of Linear Programming, Integer Programming and Game Theory.	● Introduction to linear programming problems. Mathematical formulation of LPP. Graphical solution. ● Convex sets. Basic solutions (B.S.) and non-basic solutions. Reduction of B.F.S from B.S. ● Theory of simplex method. Optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method. Big-M method and their comparison. ● 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 initial basic solution. Algorithms for solving transportation problems. ● Assignment problem and its mathematical formulation, Hungarian method for solving assignment problems. ● Travelling Salesman Problems. ● Game theory: Formulation of two-person zero sum games. ● Solving two persons zero sum games. Games with mixed strategies. Graphical solution procedure. ● Solving game using simplex algorithm.

Course: MATH-G-CC-T-04 **Course title: Linear Programming Problems & Game Theory** This course studies the fundamentals of Linear Programming: the simplex algorithm, duality theory and matrix games. We will cover the whole syllabus including the study of games: cooperative and non--cooperative games, zero sum games, non zero sum games and more.	● Introduction to linear programming problems, Graphical solution of LPP. ● Convex sets. Basic solutions and non-basic solutions. Reduction of B.F.S from B.S. ● Simplex method, two-phase method, Big- method and their comparison. ● 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's approximation method for determination of initial basic solution. Algorithms for solving transportation problems. ● Assignment problem and its mathematical formulation, Hungarian method for solving assignment problem. ● Game theory: formulation of two-person zero sum games. ● Solving two-person zero sum games. Games with mixed strategies. Graphical solution procedure. ● Solving game Using Simplex Algorithm.
Course: MATH-G-SEC-T-2A **Course title: Graph Theory** This is a standard course in graph theory, assuming little introductory knowledge of graphs. It aim is to present all usual basic concepts of graph theory, graph properties (with simplified proofs) and formulations of typical graph problems. This is also supplemented with some abstract-level algorithms for the presented problems, and with some advanced graph theory topics. At	● Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bi-partite graphs isomorphism of graphs. ● Eulerian circuits, Eulerian graphs, semi-Eulerian graphs, Hamiltonian cycles. ● Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph. ● Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm.

the end of the course, successful students shall understand in depth and tell all the basic terms of graph theory; be able to reproduce the proofs of some fundamental statements on graphs; be able to solve new graph problems; and be ready to apply this knowledge in (especially) computer science applications.	
Course: MATH-H-SEC-T-2A **Course title: Logic & Boolean Algebra** This course is designed to introduce basic concepts of Logic and Boolean Algebra to undergraduate students. After completion students will be able to use logic and boolean algebra to solve problems. • Use truth tables and laws of identity, distributive, commutative, and domination. • Simplify and prove boolean expressions • Compute sum of products and product of sum expansions. • Convert boolean expressions to logic gates and vice-versa. • Will learn about different lattices and Boolean algebra.	● Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contrapositive and inverse propositions and precedence of logical operators. ● Propositional equivalence, Logical equivalences. ● Predicates and quantifiers: Introduction, quantifiers, binding variables and negations. ● Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle. ● Lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms. ● Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal and maximal forms of Boolean polynomials. ● Quinn-McCluskey method, Karnaugh diagrams, logic gates, switching circuits and applications of switching circuits.
Course: MATH-H-CC-T-11 **Course title: Partial Differential Equations & Applications**	● 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.

This course aims to solve real life problems associated with PDEs	• 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. • 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- • 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
Course: MATH-H-CC-T-12 **Course title: Group Theory II** After completion of this course, the students will be able to demonstrate the mathematical maturity of understanding the advance aspects of Group Theory.	• 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. • 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. • 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.
Course: MATH-H-DSE-T-1A **Course title: Linear Programming**	• 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. • 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, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem. • Game theory: formulation of two persons zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.

Course: MATH-H-DSE-T-2A **Course title: Probability and Statistics** The main objective of this course is to provide students with the foundations of probabilistic and statistical analysis mostly used in varied applications in engineering and science like disease modeling, climate prediction and computer networks etc.	• 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. • 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. • 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. • Random Samples, Sampling Distributions, Estimation of parameters, Testing of hypothesis.
MATH-G-DSE-T-1A **Course title: Matrices and Linear Algebra**	• Types of matrices. Rank of a matrix. Invariance of rank under elementary transformations. Reduction to normal form, Solutions of linear homogeneous and non-homogeneous equations with number of equations and unknowns upto four. • Matrices in diagonal form. Reduction to diagonal form upto matrices of order 3.Computation of matrix inverses using elementary row operations. Rank of matrix. Solutions of a system of linear equations using matrices. • Illustrative examples of above concepts from Geometry, Physics, Chemistry, Combinatorics and Statistics. • Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces. • Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Dual Space, Dual Basis, • Double Dual, Eigen values and Eigen vectors, Characteristic Polynomial. Isomorphisms, Isomorphism
Course: MATH-G-SEC-T-3B **Course title: Vector Calculus**	• Differentiation and partial differentiation of a vector function. Derivative of sum, dot product and cross product of two vectors. • Gradient, divergence and curl with applications • Vector integration. Line, Surface and Volume integrals.

Course: MATH-H-CC-T-13 **Course title: Metric Spaces and Complex Analysis** On successful completion of the course students will be able to develop conceptual understanding of metric spaces and complex analysis. The students will be able to demonstrate understanding of the basic concepts and fundamental definitions underlying complex analysis. They can prove and explain concepts of series and integration of complex functions and clearly understand problem-solving using complex analysis, techniques.	• Metric spaces: sequences in metric spaces, Cauchy sequences. Complete metric spaces, Cantor's theorem. • Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Compactness and connectedness in metric spaceses. Compactness: Sequential compactness, Heine-Borel property, totally bounded spaces, finite intersection property, and continuous functions on compact sets. Homeomorphism.. • 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. • 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.
Course: MATH-H-CC-T-14 **Course title: Ring Theory and Linear Algebra II**	• Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients. Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, and unique factorization in Z [x]. • 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, Inner product spaces and norms, Gram-Schmidt orthogonalisation process, orthogonal complements.
Course: MATH-H-DSE-T-3B **Course title: Number Theory**	• 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. • 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.

	• 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 x2 + y2= z2, Fermat's Last theorem.
Course: MATH-H-DSE-T-4A **Course title: Mechanics** After completion of this course, the students will be able to learn and explain different concepts on Mechanics including Statics.	• Co-planar forces. Astatic equilibrium. Friction. Equilibrium of a particle on a rough curve. Virtual work.. Forces in three dimensions. General conditions of equilibrium. Centre of gravity for different bodies. Stable and unstable equilibrium. • Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law. • Equations of motion referred to a set of rotating axes. Motion of a projectile in a resisting medium. Stability of nearly circular orbits. Motion under the inverse square law. Slightly disturbed orbits. Motion of artificial satellites. Motion of a particle in three dimensions. Motion on a smooth sphere, cone, and on any surface of revolution. • Degrees of freedom. Moments and products of inertia. Momental Ellipsoid. Principal axes. D'Alembert's Principle. Motion about a fixed axis. Compound pendulum. Motion of a rigid body in two dimensions under finite and impulsive forces. Conservation of momentum and energy.
Course: MATH-G-DSE-T-2A **Course title: Linear Programming**	• Introduction to linear programming problems. 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. • 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, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem. • Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solutionof games.
Course: MATH-G-SEC-T-4A **Course title: Probability and Statistics**	• Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments,

After completion of this course, the students will be able to understand & apply the concepts of probability & statistics.	moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, continuous distributions: uniform, normal, exponential. ● 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.