Department of Mathematics

Programme Outcomes (POs) and Course Outcomes (COs)

B.Sc. Three Years Honours and General (as subsidiary course) in Mathematics (under CBCS) and B.Sc. Four Years Major and Minor (as subsidiary course) in Mathematics (under CCF)

1.(a)**Program Outcomes:**

PO1. Discipline based Knowledge: Capable of demonstrating comprehensive knowledge and understanding of mainly one discipline or other disciplines that form a part of an undergraduate program of study.

PO 2. Critical Thinking: Capable of taking actions with the use of prior information after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO3: Communication Skills: Ability to express thoughts and ideas effectively in writing and also can verbally communicate with others using appropriate idea and can present complex information in a clear and concise manner to different groups.

PO 4. Social Interaction: Ability to work effectively and respectfully with diverse teams and also can facilitate cooperative or coordinated effort on the part of a group and act together as a group or a team in the interests of a common cause.

PO 5. Moral and Ethical Awareness: Ability to embrace moral/ ethical values in conducting one's life, possess knowledge of the values and beliefs of multiple cultures and a global perspective; and capability to effectively engage in a multicultural society and interact respectfully with diverse groups.

PO 6: Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

PO 7: Information and Digital Literacy: Capability to use ICT in a variety of learning situations. Demonstrate ability to access, evaluate and use a variety of relevant information sources; and use appropriate software for analysis of data.

PO 8: Research –related skills: A sense of inquiry and capability for asking relevant/appropriate questions, synthesizing and articulating; Ability to recognize cause-and-effect relationships, define problems, formulate hypotheses, interpret and draw conclusions from data, ability to plan, execute and report the results of an experiment or investigation. Ability to apply one's learning to real life situations.

PO 9: Employability: After completion of the program students become employable on the basis of their qualification, acquired knowledge and skills.

1.(b)**Course Outcomes:**

CBCS:

SEMESTER I

Learning Outcomes of *Core Course-1*

Unit-1: Calculus

Students learn about different types of curves, their properties and how to trace them. They learn how to tackle the problems related to indeterminate forms and successive differentiation. They learn the applications of Integration and Differentiation to find the length, area, volume of geometrical figures.

Unit-2: Geometry

They learn to classify different conics and study their properties. In three dimensions, they learn about lines, planes and spheres.

Unit-3: Vector Analysis

They learn to apply vector algebra and calculus in geometrical and physical problems.

Learning Outcomes of *Core Course-2*

Unit-1

Complex Numbers

They learn the polar representation of complex numbers and exponential, logarithmic, hyperbolic and trigonometric functions of complex variables.

Theory of Equations

They learn different special methods for locating and solving algebraic equations.

Inequalities

They will acquire basic knowledge of inequalities.

Linear Difference Equations

They learn to discretize the continuous problems and solve it using finite difference operators.

Unit-2

Relations and Mappings

They will be able to learn basic concepts of Abstract Algebra including relation and mapping.

Integers

They learn basic properties of integers, prime numbers and applications of congruence.

Unit-3: Matrices and Systems of Linear Equations

They learn about rank, inverse of a matrix and their applications in solving systems of linear equations.

Learning Outcomes of *GE-I*

1. They learn the polar representation of complex numbers and exponential, logarithmic and trigonometric functions of complex variables.
2. They learn about rank, inverse of a matrix and their applications in solving systems of linear equations.
3. They learn how to tackle the problems related to indeterminate forms and successive differentiation.
4. They learn to classify different conics and study their properties. In three dimensions, they learn about lines, planes.
5. Classifies the differential equations with respect to their order and linearity. Expresses the basic existence theorem for higher- order linear differential equations.

SEMESTER II

Learning Outcomes of *Core Course-3*

The learning outcomes of this course are:

1. Understand real numbers: properties, operations, and order.

2. Analyze sets: countable and uncountable sets, bounded and unbounded sets.

3. Apply limit concepts: limit points, isolated points, and Bolzano-Weierstrass theorem.

4. Work with sequences: convergence, boundedness, uniqueness of limits, and Cauchy sequences.

5. Understand series convergence: tests for convergence and divergence, absolute and conditional convergence.

6. Develop problem-solving skills: using real analysis techniques to solve mathematical problems.

7. Demonstrate mathematical rigor: understanding and applying mathematical definitions, theorems, and proofs.

8. Communicate mathematical ideas: clearly and effectively presenting real analysis concepts and solutions.

By the end of the course, students should be able to:

- Apply real analysis concepts to solve problems

- Prove mathematical statements using real analysis techniques

- *Communicate complex mathematical ideas effectively*

- *Demonstrate a deep understanding of real analysis concepts and their applications.*

Learning Outcomes of *Core Course-4*

Unit-1: Groups and Subgroups

Students learn the basic abstract algebraic structure 'Group' and its properties. They also learn about subgroups of a group.

Unit-2: Cyclic Groups and Permutation Groups

They learn about different properties of cyclic groups and permutation groups. They also learn Lagrange's theorem and consequences including Fermat's Little theorem.

Unit-3: Normal Subgroups and Homomorphism

They learn about Normal subgroups and Quotient groups. They also get the idea of Homomorphism and study their properties including different Isomorphism theorems.

Learning Outcomes of GE-2

Unit-1: Differential Calculus-II

1.know the concept of convergence and divergence of a sequence of real numbers and different properties of a sequence including Cauchy's general principle of convergence.
2. understand the concept of convergence of an infinite series and apply different tests of convergence like D'Alembert's ratio test. Cauchy's root test, Raabe's test, Leibnitz test, etc.
3. understand and apply Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Taylor's theorem.
4. expand different functions as infinite series.
5. apply L' Hospital's rule.
6. determine principles of local maximum/minimum of functions (for functions not more than three variables) and apply these principles in different problems.

Unit-2: Differential Equation-II

1. solve different linear homogeneous equations with constant coefficients, Linear non-homogeneous equations.
2. understand the method of variation of parameters.
3. know about the Cauchy-Euler equation.
4. solve simultaneous differential equations and simple eigenvalue problem.
5. formulate partial differential equations.
6. solve partial differential equations by Lagrange's method and Charpit's method.

Unit-3: Vector Algebra

1. know about addition of vectors, multiplication of a vector by a scalar.
2. understand collinear and coplanar vectors.

3. get ideas of scalar and vector products of two and three vectors and apply them to problems of Geometry.
4. find vector equation of planes and straight lines.
5. compute volume of a tetrahedron by vector method.
6. apply vector algebra problems of Mechanics (work done and moment).

Unit-4: Discrete Mathematics

1. know the principle of mathematical induction, division algorithm and idea of representation of an integer in an arbitrary base.
2. get idea of prime Integers and learn about some properties of prime integers.
3. understand congruence relation on integers and know basic properties of this relation.
4. understand and apply Chinese remainder theorem and solve of a system of linear congruence.
5. apply congruence to divisibility tests, to find check-digit in an ISBN, in universal product code, and in major credit cards.
6. get idea of addition and multiplication of congruence classes.
7. understand and apply Fermat's little theorem, Euler's theorem and Wilson's theorem. Some simple applications.
8. know about Boolean Algebra, Boolean functions and logic gates and use these for minimization of circuits.

SEMESTER III
Learning Outcomes of Core Course-5

1. know the $\in$-δ approach of limit of a function and sequential criterion of limit.

2. understand algebra of limits and find different important limits.

3. get the concept of continuity, its sequential criterion; and be familiar with different continuous functions.

4. know neighbourhood property of continuous functions.

5. understand and apply results like boundedness property, Bolzano's theorem on continuity, intermediate value theorem, etc.

6. identify different types of discontinuities.

7. deal with continuity of monotonic functions and inverse functions.

8. get ideas of uniform continuity, Lipschitz functions, and their relations.

9. get the concept of differentiability of a function, understand algebra of differentiable functions and meaning of sign of derivative.

10. understand and apply Darboux theorem, Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Taylor's theorem

11. expand different functions as infinite series.

12. apply L' Hospital's rule.

13. determine principles of local maximum/minimum of functions using derivatives and apply these principles in different problems.

Learning Outcomes of Core Course- 6

1. At the end of course, students will be able to know about a new branch of Algebra. This course provides an axiomatic description of an abstract vector space with different types of examples, concepts of basis, different ways to form basis according to own choice and concept of subspaces (with Geometrical interpretation).

2. Another important topic of this course is linear transformation. Students will be able to construct different types of mappings on vector spaces with special property linearity. This course makes them understand the concept of nullity, rank and relation between them (according to the basic property of a mapping such as injection, surjection, bijection).

3. Students will be surprised to see the relation between matrices and linear transformations, the change of matrix presentation of a linear transformation with the change of base of vector spaces and related theorems.

4. At last the course will provide the concept of eigenvalue, eigenvector, Cayley-Hamilton theorem and their application in Algebra.

Learning Outcomes of Core Course-7

Unit:1 (Ordinary Differential Equations)

1. Students are able to distinguish between linear, nonlinear, partial and ordinary differential equations.

2. Classifies the differential equations with respect to their order and linearity.

3. Expresses the basic existence theorem for higher- order linear differential equations.

4. Able to use the rules of different integrating factors in various non-exact equations.

5. Able to understand the concept of Linear dependent and independent solutions (Wronskian).

6. To inculcate knowledge on solving of first and second order differential equations with algebraic manipulations.

7. Applies the method of undetermined coefficients to solve the non-homogeneous linear differential equations with constant coefficients. Uses the method "variations of parameters" to find to solution of higher-order linear differential equations with variable coefficients.

8. Create and analyses mathematical models using first order differential equations to solve application problems such as circuits, mixture problems, population modelling, orthogonal trajectories, and slope fields.

9. Create and analyses mathematical models using higher order differential equations to solve application problems such as harmonic oscillator and circuits.

10. Communicate mathematical applications, concepts, computations, and results with classmates and colleagues in the fields of science, technology, engineering, and mathematics.

Unit: 2 (Multivariate Calculus I)

1. Analyse real world scenarios to: recognize when vectors, geometry of space, multivariate and vector functions, partial differentiation, and multiple integration are appropriate, formulate and model these scenarios (using technology, if appropriate) in order to find solutions using multiple approaches, judge if the results are reasonable, and then interpret these results.
2. Recognize the underlying mathematical concepts of vectors, geometry of space, multivariate and vector functions, partial differentiation, and multiple integration.

Learning Outcomes of GE-3

1. At the end of the course students can get a precise knowledge about Integral Calculus , Numerical Methods and Linear Programming .In Integral Calculus they will learn definite integral , improper integral , double integral , volume integral , surface integral and their applications.
2. In Numerical Methods they will be familiar with different numerical operators, different types of interpolation, numerical integration, solution of numerical equation.
3. In Linear Programming they will know use of linear programming in real life problem, formulation of L.P.P. and solving them using different methods like graphical method, simplex method, dual method.

Learning Outcomes of SEC-A (C Programing Language)

What the students learn from the course of **C Programming Language**

1. C is robust language and has rich set of built-in functions (Library Functions) , data types and operators which can be used to write any

complex program.

2. Program written in C are efficient due to availability of several data types and operators.

3. C has the capabilities of an assembly language (low level features) with the feature of high level language so it is well suited for writing both system software and application software.

4. C is highly portable language i.e. code written in one machine can be moved to other which is very important and powerful feature.

5. Another very important feature of C Programming Language is that it allows users to define User Defined Functions according to their need.

6. Single list of instructions within main() functions are known as monolithic program – i.e. program containing a large single list of

instructions. These types of programs are very difficult to understand, debug, test and maintain. So to avoid these difficulties we use user defined functions.

7. User defined functions in C programming has following advantages:

8. Reduction in Program Size: Since any sequence of statements which are repeatedly used in a program can be combined together to form a user defined functions. And this functions can be called as many times as required. This avoids writing of same code again and again reducing program size.

9. Reducing Complexity of Program: Complex program can be decomposed into small sub-programs or user defined functions.

10. Easy to Debug and Maintain: During debugging it is very easy to locate and isolate faulty functions. It is also easy to maintain program that uses user defined functions.

11. Readability of Program: Since while using user defined function, a complex problem is divided in to different sub-programs with clear objective and interface which makes easy to understand the logic behind the program.

12. Code Reusability: Once user defined function is implemented it can be called or used as many times as required which reduces code repeatability and increases code reusability.

SEMESTER IV
Learning Outcomes of Core Course-8

1. The Riemann integral is often introduced to undergraduate calculus students, as its definition and related theorems are relatively straightforward to understand.
2. Sir Isaac Newton and Gottfried Leibniz discovered that integration being a process of summation, was inverse to the operation of differentiation. A century and a half later Bernhard Riemann separated the concept of integration from its companion differentiation and examined the motivating summation and limit process of finding areas by itself. All functions defined on a negligible set are the ones which are Riemann integrable.
3. Lebesgue criterion for integration is studied. A bounded function is Riemann integrable if and only if it is continuous almost everywhere on [a,b]. The sum , Product, modulus and quotient of two integrable functions are integrable. Antiderivative (primitive or indefinite

integral).

4. Necessary and Sufficient Conditions of Integrability of functions is given by the Darboux Theorem. Fundamental Theorem of Integral Calculus and First Mean Value theorem of integral calculus is also introduced which helps students to solve large variety of problems of Physics, Engineering and interdisciplinary subjects.

Learning Outcomes of Core Course- 9

Unit-1 (Partial Differential Equations)

On successful completion of this course students will be able to:

1. know basics of partial differential equations (PDEs), their constructions, classifications, and different terminologies.

2. get knowledge of first order PDEs, get the concept of characteristics, know about Lagrange's method of solution for quasi-linear first order equations, and apply it to solve different problems.

3. get ideas about nonlinear first order partial differential equations, learn about Charpit's general method of solution, and apply it some special types of equations.

4. derive heat equation, wave equation and Laplace equation.

5. classify second order linear equations as hyperbolic, parabolic or elliptic.

6. reduce second order linear PDEs to canonical forms.

7. get ideas of initial value problems (the Cauchy problem) and the famous Cauchy-Kowalewskaya theorem.

8. know about the D'Alembert solution of homogeneous wave equations and its physical significance.

9. understand initial and boundary value problems.

10. solve problems of semi-infinite string with a fixed end and semi-infinite string with a free end.

11. find solutions of equations with non-homogeneous boundary conditions.

12. handle non-homogeneous wave equation.

13. use the method of separation of variables for solving the vibrating string problem and the heat conduction problem, etc.

Learning Outcomes of Core Course-10

What the students learn from the course of **Analytical Statics**

1. Mechanics (derived from a Greek word meaning "contrivances" i.e. gadgets, mechanical devices, contraptions) can be defined as that branch of the applied sciences that describes and predicts the conditions of rest or motion of bodies that are subjected to the action of forces.

2. There are different branches of Mechanics among which Statics is one

3. Statics is of great importance because many devices are engineered with the intention that they remain in static equilibrium.

4. Analytical Statics is the branch of mechanics that deals with bodies at rest or forces in equilibrium.

5. It helps one to solve 2-D and 3-D rigid body equilibrium problems

6. Moments and couple moments using scalars and vectors in 2-D and 3-D can be calculated.

7. The learners understand the difference between static and kinetic friction.

8. Statics can be applied to a variety of situations.

9. Since statics is a special case of Newton's laws, both the general problem-solving strategies and the special strategies for Newton's laws still apply.

10. Static, sliding, and rolling friction occur between solid surfaces. Static friction is strongest, followed by sliding friction, and then rolling friction, which is weakest.

On successful completion of the course **"Mechanics"** students will be able to:

1. understand the concept of relative motion. Inertial and non-inertial reference frames. Parameters defining the motion of mechanical systems and their degrees of freedom.

2. Concept of forces, angular momentum and knowledge about the Constraint. The course will give knowledge about the general parameter like velocity, acceleration.

3. Application of the vector theorems of mechanics and interpretation of their results.

4. Newton's laws of motion and conservation principles. Introduction to analytical mechanics as a systematic tool for problem solving. The student will be able to model physical structures and processes with calculus based techniques and produce a solution (either analytical or numerical).

5. The student will be able to synthesize Newtonian Physics with static analysis to determine the complete load impact (net forces, shears, torques, and bending moments) on all components (members and joints) of a given structure with a load.

Learning Outcomes of SEC-B1 (Mathematical Logic)

1. Mathematical Logic belong to the area of Discrete Mathematics. It was first explained by the Greek Philosopher Aristotle. It is the basis of all mathematical reasoning and of all automated reasoning. PROLOG language which is abbreviation of 'Programming in Logic' was used in Artificial Intelligence. The area of logic is divided into two categories: Propositional Logic and Predicate Logic

2. Propositions, truth table and logical operators are introduced. Formal theory for propositional calculus, Deduction theorem, conjunctive and disjunctive normal forms, applications to switching circuits, Leindenbaum lemma, soundness and completeness theorems, are studied.

3. Another more powerful logic the Predicate Logic is also studied. An expression of one or more variables defined on some specific domain is called a predicate.

4. First order language, symbolizing ordinary sentences into first order formulae, free and bound variables, formal theory for predicate calculus, theorems and derivations, deduction theorem, equivalence theorem, replacement theorem, Prenex normal form, soundness theorem, completeness theorem, compactness theorem, examples of First Order Theories (groups, rings, fields etc.) are studied.

Learning Outcomes of GE-4

Students will learn from this course

1. Historical Development, Computer Generation, Computer Anatomy Different Components of a computer system. Operating System, hardware and Software.
2. Binary to Decimal and Decimal to Binary. Other systems.
3. Ideas about some HLL– e.g. BASIC, FORTRAN, C, C++, COBOL, PASCAL, etc.
4. Definitions and examples of (i) Ring, (ii) Field, (iii) Sub-ring, (iv) Sub- field.
5. Examples, Concepts of Linear combinations, Linear dependence and independence of a finite number of vectors, Sub- space.

6. To understand the basic principles of probability including the laws for unions, intersections, and complementation, Bayes theorem and use these principles in problem solving situations. Apply the basic probability rules, including additive and multiplicative laws, independent and mutually exclusive events in probability models.

7. Calculate statistics such as the mean and variance of common probability distributions. Summarize the roles of different distributions in practical situations and illustrate with examples the nature of limiting distributions for large samples.

SEMESTER V
Learning Outcomes of Core Course-11

On successful completion of the course students will be able to:

1. To understand the basic principles of probability including the laws for unions, intersections, and complementation, Bayes theorem and use these principles in problem solving situations. Apply the basic probability rules, including additive and multiplicative laws, independent and mutually exclusive events in probability models.

2. Understand the concept of Sigma-algebra and concept of probability space based on sigma algebra.

3. Understand the definitions of discrete, continuous, and joint random variables, compute the mean, variance and covariance of random variables, know the definition of mass (density) function and distribution function of a random variable and be able to find one from the other, and be able to find the marginal mass (density) function and distribution functions from the joint mass (density) function and distribution function.

4. Identify an appropriate probability distribution for a given discrete or continuous random variable and use its properties to calculate probabilities.

5. Calculate probabilities for joint distributions including marginal and conditional probabilities.

6. Calculate the moments and formulates the Moment Generating Function, Characteristic Function.

7. Calculate statistics such as the mean and variance of common probability distributions. Summarize the roles of different distributions in practical situations and illustrate with examples the nature of limiting distributions for large samples.

8. To develop a questionnaire, organize a sample survey by implementing different sampling techniques and predict population characteristics.

9. Explain the desirable properties of estimators. Calculate and interpret maximum likelihood estimates and their confidence intervals.

10. Explain the role of probability in hypothesis testing and describe issues related to interpreting statistical significance.

11. One area that needs to be strengthened in response to the career climate is student preparation in statistics and data science. The Higher Education recently listed the growth of data science programs as a key trend in higher education. However, they also noted that data science programs are being added without careful attention to what a data science curriculum should look like. Moreover, because data and statistics play an important role in all disciplines, undergraduate curriculum in statistics and data science may be embedded within different disciplinary contexts. As such, there is a need for a set of comprehensive learning outcomes to help guide data learning across the disciplines.

Learning Outcomes of Core Course-12

Unit 1 Group Theory

On successful completion of this unit, the student will learn the followings:

(Group is a part of Abstract Algebra which includes a solid introduction to the traditional topics of mathematics. There is a connection between abstract algebra, number theory and geometry. Students have been given the definition of groups, various examples of groups and large number of group properties in the previous classes. Cyclic groups, Group Homomorphism and Isomorphism concepts are known to the students.)

1. In this unit, Automorphism ,which is an isomorphism of a group onto itself, is introduced. The set of all automorphisms on a group onto itself forms a group under composition of mappings and is called the Automorphism group. The students will enjoy the beauty of automorphism groups of finite and infinite cyclic groups

2. Symmetry itself is a vast subject, significant in art and nature. Mathematics lies at its roots. External Direct Product and Internal Direct Product of groups are introduced. The students will be able to get a better insight to the fact that the Universe is an enormous Direct Product Representation of Symmetry groups . The Properties of Finite Abelian groups will help them to study the Sylow’s Theorems

3. The concepts and methodologies are used by applied mathematician. Computer scientists, physicists and chemists.

Unit 2 Linear Algebra

On successful completion of this unit, the student will learn the followings:

(Vector Spaces and related concepts are fundamental parts of Linear Algebra.

Also, Linear Transformations and related concepts are also very important in Linear Algebra. They are introduced earlier classes.)

1. The student will learn the concept of Inner product spaces and norms.

They will be able to form orthonormal basis with the help of Gram-Schmidt orthgonalisation.

They will be acquainted with Bilinear form and Quadratic form and will be able to diagonalise symmetric matrix and will be able to find index and signature of a symmetric matrix.

2.They will learn the concept of Dual Space and transpose of a linear transformation. Also, they will learn the idea of eigenspace, diagonlisability, minimal polynomial and Jordan canonical form.

Learning Outcomes of DSE-A1-1(Advanced Algebra)

On successful completion of this course, students will learn the following:

1.Demonstrate a deep understanding of advanced abstract algebraic structures such as groups, rings, fields, and modules.

2.Apply advanced concepts and theorems in abstract algebra to solve complex mathematical problems.

3.Develop the ability to construct rigorous mathematical proofs for advanced theorems in abstract algebra.

4.Explore and understand the proofs of key theorems like the structure theorems for groups and rings.

Learning Outcome of DSE-B1-2: Linear Programming and Game Theory)

After the completion of this course students will be able to:

1) mathematically formulate an applied word problem involving revenue, costs, and constraints as a linear program.

2) apply the simplex algorithm to solve a linear programming problem.

3) utilize computer software to solve a linear programming problem.

4) solve a linear programming problem using either the Big M-Method or the Two-Phase Simplex Method.

5) describe the Dual Theorem and its consequences.

6) use duality to analyse changes to a linear programming problem’s optimal solution.

7) solve the transportation and assignment problems which are very much related to industrial problems.

8) solve two person zero sum games with the help of algebraic method and Linear Programming method which has huge application in industry

SEMESTER VI

Learning Outcomes of Core Course-13

1. Metric Space is a part of Functional Analysis which is an abstract branch of mathematics that originated from classical analysis. It plays an increasing role in applied sciences as well as in mathematics itself. Metric space plays a role similar to that of the real line **R** in calculus

2. A metric space is a set X with a metric d (distance function on X) satisfying certain axioms. The concept of open sets, closed sets, interior point, limit point, bounded sets, diameters of sets are included in the course. Convergent sequence are very important concepts in real analysis as well as in Metric spaces.

3. The learners understand the ideas of completeness properties in **R** and in a general metric spaces. Cauchy's criterion of convergence of sequences play an important role in R. Every convergent sequence is Cauchy and bounded, but the converse is not true in a metric space. R is a complete metric space. Q is not.

4. They study the Cantors Intersection Theorem which gives a necessary and sufficient condition for completeness of a metric space. Continuity and Uniform continuity of functions between two metric spaces are studied essentially in analogous ways as is done for the real valued functions on **R.** Open cover and compactness are introduced and certain theorems follow from these concepts. Idea of Connectedness is also given with examples from **R**

5. By studying the Contraction theorem and Banach Fixed point Theorem students will be able to understand the iteration methods for solving system of linear algebraic equations and yield sufficient conditions for convergence and error bounds.

6. After successful completion of the course, students will be able to understand the concept of stereographic projection, different kinds of complex valued functions and their limit, continuity, differentiability and analyticity. They will know a new transformation namely Mobius Transformation, its different properties and applications. They will also understand Cauchy theorem and Cauchy integral formulas and application of these to evaluate complex

contour integrals. At last students will know about complete concept of Power series of complex variable.

Learning Outcomes of Core Course-14

1. Numerical analysis is one of part of mathematics. To deal with a physical problem one often tries to construct a mathematical model. These models in general lead to a differential equation or difference equation which cannot be solved analytically in very few situations one can get analytic solution. Therefore, one has to adopt approximate methods or numerical methods. These methods are based on series expansions or they may be purely numerical leading to the estimation of the unknown at specific points in its interval of definition by simple arithmetic means.

2. Approximation Theory and Numerical Analysis are closely related areas of mathematics. Approximation Theory lies in the crossroads of pure and applied mathematics. It includes a wide spectrum of areas ranging from abstract problems in real, complex, and functional analysis to direct applications in engineering and_industry. Therefore, Approximation Theory employs a great variety of methods, which originate in analysis, operator theory, harmonic analysis, quantum calculus, algorithms, probability theory, and further areas of mathematics.

3. Mathematical problems arising from scientific applications present a wide variety of difficulties that prevent us from solving them exactly. This has led to an equally wide variety of techniques for computing approximations to quantities occurring in such problems in order to obtain approximate solutions.

4. Determining the condition, or sensitivity, of a problem is an important task in the error analysis of an algorithm designed to solve the problem, but it does not provide sufficient information to determine whether an algorithm will yield an accurate approximate solution.

5. Is it always reasonable to assume that any approximate solution is the exact solution to a nearby problem? Unfortunately, it is not. It is possible that an algorithm that yields an accurate approximation for given data may be unreasonably sensitive to perturbations in that data. This leads to the concept of a stable algorithm: an algorithm applied to a given

problem with given data x is said to be stable if it computes an approximate solution that is the exact solution to the same problem with data xˆ, where xˆ is a small perturbation of x.

6. It can be shown that if a problem is well-conditioned, and if we have a stable algorithm for solving it, then the computed solution can be considered accurate, in the sense that the relative error in the computed solution is small. On the other hand, a stable algorithm applied to an ill-conditioned problem cannot be expected to produce an accurate solution.

7. The calculus of finite differences is the study of changes in the dependent variable y=f(x) with respect to the finite changes in the independent variable in finite difference we study many operators such as forward difference operators, backward difference operators, central difference operators, shift operators, averaging operator etc. We also study the interpolations for equal intervals and unequal intervals. Interpolation is also defined as the technique of estimating the function for any intermediate value of interpolations is the art of reading between the lines of a table. Interpolation can be think of a technique of achieving the most likely estimate of a certain quantity under certain specific assumptions.

8. Central difference interpolation formulae are used for interpolating the functional value near the middle of a given set of data.

9. Just like differential equations, the difference equations play a important role in dealing with the problems of economics, social and other science, especially in mathematical models corresponding to a given physical problem. Hence it is essential to study the difference equations. Numerical differentiation is the process of evaluating the derivative of a function at a point when the exact form of function is not known. For this, one can obtain the suitable polynomial which is the best fit for the given_data by the means of suitable interpolation formula and then known but a set of values of that function is known.

10. The problem of numerical integration is solved by approximating the integrand by a polynomial with the help of an interpolation formula and then integrating the expansion between the desired limits.

11. Methods for finding the numerical solution of first order differential equations having numerical coefficient with given initial conditions to any desired degree of accuracy. The solution is obtained step by step through a series of equal intervals in the independent variable.

12. Solution of algebraic and transcendental equations is also possible in numerical technique by bisection method, Regula Falsi method, Newton Raphson method, Iteration method etc.

Learning Outcomes of DSE-A2-2(Mathematical Modelling)

On successful completion of this course, students will learn the following:

1. Gain a deep understanding of the fundamental concepts and principles of mathematical modelling.

2. Comprehend how mathematical structures and techniques can be applied to real-world problems

3. Develop the skills to formulate mathematical models that represent complex systems or phenomena in various disciplines.

4. Learn numerical techniques for simulations and solutions of models that may not have closed-form solutions

5. Analyse algebraic structures and study the properties of homomorphism between them.

Learning Outcomes of DSE-B2-1(Point Set Topology)

1. They will learn the basic idea of topology and related concepts. The idea of Continuous mapping, open and closed mapping and homeomorphism will be learned by them.

2. They will learn the separation axioms and the idea of first and second countability.

3. They will also learn the concepts of connected and compact topological spaces.

4. They will learn the concepts of sequence in a topological space and the idea of sequential compact spaces.

5. The idea of metric topology and related concepts and isometry will also be learned by them.

1.(c)**Course Outcomes: (under CCF)**

SEMESTER I

Learning Outcomes of *MATH-H-CC1-1-Th*

Group A: Calculus

Students learn about different types of curves, their properties and how to trace them. They learn how to tackle the problems related to indeterminate forms and successive differentiation. They learn the applications of Integration and Differentiation to find the length, area, volume of geometrical figures.

Group B: Geometry

They learn to classify different conics and study their properties. In three dimensions, they learn about lines, planes and spheres.

Group C: Vector Analysis

T*hey learn to apply vector algebra and calculus in geometrical and physical problems.*

Learning Outcomes of MATH-H-SEC1-1-Th

What the students learn from the course of **C Language with Mathematical Applcations:**

1. C is robust language and has rich set of built-in functions (Library Functions) , data types and operators which can be used to write any

complex program.

2. Program written in C are efficient due to availability of several data types and operators.

3. C has the capabilities of an assembly language (low level features) with the feature of high level language so it is well suited for writing both system software and application software.

4. C is highly portable language i.e. code written in one machine can be moved to other which is very important and powerful feature.

5. Another very important feature of C Programming Language is that it allows users to define User Defined Functions according to their need.

6. Single list of instructions within main () functions are known as monolithic program – i.e. program containing a large single list of instructions. These types of programs are very difficult to understand, debug, test and maintain. So to avoid these difficulties we use user defined functions.

7. User defined functions in C programming has following advantages:

8. Reduction in Program Size: Since any sequence of statements which are repeatedly used in a program can be combined together to form a user defined functions. And this functions can be called as many times as required. This avoids writing of same code again and again reducing program size.

9. Reducing Complexity of Program: Complex program can be decomposed into small sub-programs or user defined functions.

10. Easy to Debug and Maintain: During debugging it is very easy to locate and isolate faulty functions. It is also easy to maintain program that uses user defined functions.

11. Readability of Program: Since while using user defined function, a complex problem is divided in to different sub-programs with clear objective and interface which makes easy to understand the logic behind the program.

12. Code Reusability: Once user defined function is implemented it can be called or used as many times as required which reduces code repeatability and increases code reusability.

13. Mathematical Applications: C Language has many applications in various field of Mathematics such as Linear Algebra , Abstract Algebra, Differential Equations and it has huge applications in Numerical Methods.

Learning Outcomes of *MATH-H-MC 1-1-Th:*

Same as MATH-H-CC1-1-Th.

Learning Outcomes of *MATH-H-IDC-1-Th:*

Group A: The students learn basic concepts of set theory which is needed now in every field of Science subjects and also they are now used in Commerce and Art fields also to represent something in compact and precise form.

Group B: They learn about integers and modular arithmetic. It has huge applications in Cryptography to cipher and decipher codes. They learn some of them.

Group C: They learn about the propositional calculus in Mathematical Logic and there they learn about the construction of proof and also learn how to think logically without error.

Group D: Here they learn about basics of Operational Research which are Linear programming and game theory and they learn use it in their daily life and for job in industry.

Group E : They learn about Financial Mathematics where they learn to calculate simple and compound interests and annuities and also they learn to calculate dividend and income tax on taxable income in new and old regime.

SEMESTER II

Learning Outcomes of *MATH-H-CC2-2-TH:*

Group A:

Complex Numbers

They learn the polar representation of complex numbers and exponential, logarithmic, hyperbolic and trigonometric functions of complex variables.

Theory of Equations

They learn different special methods for locating and solving algebraic equations.

Inequalities

They will acquire basic knowledge of inequalities.

Group B

Relations and Mappings

They will be able to learn basic concepts of Abstract Algebra including relation and mapping.

Integers

They learn basic properties of integers, prime numbers and applications of congruence.

Group C:

Matrices and Systems of Linear Equations

They learn about rank, inverse of a matrix and their applications in solving systems of linear equations. They also learn about vectors and their independence and dependence in Euclidean space.

Learning Outcomes of *MATH-H-SEC 2.1-2-Th:*

Based on the course syllabus, the learning outcomes for the Python programming and LaTeX course can be summarized as follows:

Python Programming:

1. Understand the basics of Python programming, including data types, variables, control structures, functions, and modules.

2. Learn to write Python programs to solve problems, including numerical computations, data analysis, and visualization.

3. Understand how to work with different data structures, such as lists, tuples, and dictionaries.

4. Learn to use the SymPy library for symbolic mathematics and algebra.

5. Understand how to create visualizations using SymPy.

LaTeX:

1. Understand the basics of LaTeX, including document classes, page layout, and formatting.

2. Learn to create professional-looking documents, including research articles, reports, and presentations.

3. Understand how to typeset mathematical equations and formulas using LaTeX.

4. Learn to customize fonts, layouts, and formatting in LaTeX documents.

5. Understand how to use different LaTeX packages and environments.

Overall:

1. Develop problem-solving skills using Python programming.

2. Learn to communicate technical ideas and results effectively using LaTeX.

3. Understand the importance of documentation and reporting in technical fields.

4. Develop skills in data analysis, visualization, and presentation.

5. Learn to use programming and typesetting tools to create professional-looking documents and presentations.

Learning Outcomes of *MATH-H-MC 2-2-Th:*

Same as MATH-H-CC2-2-Th.

Learning Outcomes of *MATH-H-IDC-2-Th:*

Same as MATH-H-IDC-1-Th.

SEMESTER III

Learning Outcomes of *MATH-H-CC3-3-Th:*

The learning outcomes of this course are:

1. Understand real numbers: properties, operations, and order.

2. Analyze sets: countable and uncountable sets, bounded and unbounded sets.

3. Apply limit concepts: limit points, isolated points, and Bolzano-Weierstrass theorem.

4. Work with sequences: convergence, boundedness, uniqueness of limits, and Cauchy sequences.

5. Understand series convergence: tests for convergence and divergence, absolute and conditional convergence.

6. Develop problem-solving skills: using real analysis techniques to solve mathematical problems.

7. Demonstrate mathematical rigor: understanding and applying mathematical definitions, theorems, and proofs.

8. Communicate mathematical ideas: clearly and effectively presenting real analysis concepts and solutions.

By the end of the course, students should be able to:

- Apply real analysis concepts to solve problems

- Prove mathematical statements using real analysis techniques

- Communicate complex mathematical ideas effectively

- Demonstrate a deep understanding of real analysis concepts and their applications.

Learning Outcomes of MATH-H-CC4-3-Th:

The learning outcomes of this course are:

Ordinary Differential Equations (ODE) - I

1. *Formulate and solve differential equations: First-order and higher-order linear and nonlinear equations.*
2. *Analyze and classify differential equations: Identify order, degree, and type of differential equation.*
3. *Apply various solution methods: Integrating factors, separation of variables, undetermined coefficients, and variation of parameters.*
4. *Solve systems of linear differential equations: Using methods like substitution and elimination.*
5. *Understand the properties of solutions: Existence, uniqueness, and stability of solutions.*

Group Theory - I

1. *Define and identify groups: Recognize examples of groups, including permutation, dihedral, and quaternion groups.*
2. *Understand group properties: Closure, associativity, identity, and inverse.*
3. *Analyze subgroups and their properties: Determine if a subset is a subgroup, and identify normalizers, centralizers, and centers.*
4. *Calculate the order of elements and groups: Determine the order of an element and a group.*
5. *Apply group theory concepts: Permutations, cycles, and alternating groups.*

Overall Learning Outcomes

1. *Develop problem-solving skills: Apply mathematical techniques to solve problems in ODEs and group theory.*
2. *Demonstrate mathematical rigor: Understand and apply mathematical definitions, theorems, and proofs.*

3. Communicate mathematical ideas: Clearly and effectively present mathematical concepts and solutions.

4. Apply mathematical concepts to real-world problems: Recognize the relevance of ODEs and group theory to physics, engineering, and computer science.

Learning Outcomes of *MATH-H-MC 1-3-Th:*

Same as MATH-H-MC 1-1-Th

Learning Outcomes of MATH-H-IDC-3-Th:

Same as MATH-H-IDC-1-Th

SEMESTER IV

Learning Outcomes of *MATH-H-CC 5-4-TH:*

The learning outcomes of the Theory of Real Functions course are:

Group A: Limit and Continuity of Functions

1. Understand limits of functions (ε-δ approach) and sequential criterion.
2. Apply limit theorems, one-sided limits, and infinite limits.
3. Analyze continuity of functions on intervals and at isolated points.
4. Understand oscillation of functions and its relation to continuity.
5. Recognize properties of continuous functions, such as algebra of continuous functions.
6. Apply intermediate value theorem and Bolzano's theorem.
7. Understand discontinuity of functions, including step functions and piecewise continuity.
8. Analyze monotone functions and their properties.
9. Understand uniform continuity and its relation to continuity on closed and bounded intervals.

Group B: Differentiability of Functions

1. Apply Darboux theorem, Rolle's theorem, and mean value theorems.
2. Understand Taylor's theorem and its applications, including expansion of functions.
3. Analyze local extrema of functions and sufficient conditions for their existence.

4. Apply the principle of maximum/minimum in geometrical problems.

Overall Learning Outcomes

1. Develop problem-solving skills in real analysis.
2. Demonstrate understanding of limits, continuity, and differentiability of functions.
3. Apply mathematical concepts to solve problems in physics, engineering, and other fields.
4. Communicate mathematical ideas effectively.
5. Develop critical thinking and analytical skills in mathematics.

Learning Outcomes of *MATH-H-CC 6-4-TH:*

The learning outcomes of this course are:

Statics-I

1. Understand the principles of forces: Physical Independence Principle, transmissibility, action and reaction, and parallelogram law.
2. Apply composition and resolution of forces, concurrent forces, and equilibrium conditions.
3. Calculate moments of forces and resultant forces and couples.

Particle Dynamics-I

1. Understand Newton's laws of motion, equation of motion, and rectilinear motion in various force fields.
2. Analyze simple harmonic motion, damped and forced oscillations, and resonance.
3. Apply concepts of work, power, energy, and conservative forces.
4. Understand impulse, impulsive forces, and conservation of linear momentum.
5. Analyze collisions, coefficient of restitution, and Newton's law of collision.

Motion of a Particle in a Plane

1. Understand 2D Cartesian motion: angular velocity, acceleration, and components of velocity and acceleration.
2. Analyze 2D polar motion: central forces, central orbits, and motion under inverse square law.
3. Apply Kepler's laws on planetary motion and understand motion of artificial satellites.
4. Understand constrained motion of a particle on a smooth curve.

Overall Learning Outcomes

1. Develop problem-solving skills in mechanics.
2. Demonstrate understanding of fundamental principles: forces, motion, energy, and momentum.
3. Apply mathematical models to solve problems in physics and engineering.
4. Analyze and interpret physical phenomena using mechanical principles.
5. Develop critical thinking and analytical skills in mechanics.

Learning Outcomes of *MATH-H-CC 7-4-TH:*

The learning outcomes of the

course are:

Multivariate Calculus - I

1. Understand limits, continuity, and differentiability of multivariable functions.
2. Apply partial derivatives, directional derivatives, and gradient vectors.
3. Understand higher-order partial derivatives, Schwarz's and Young's theorems, and Taylor's theorem.
4. Analyze implicit functions, Jacobians, and extrema of multivariable functions.
5. Understand multiple integrals, including double and triple integrals, and change of variables.
6. Apply Fubini's theorem, iterated integrals, and transformation of integrals.

Partial Differential Equations - I

1. Define and classify partial differential equations (PDEs).

2. Derive PDEs and understand their importance in science and technology.

3. Solve first-order quasilinear PDEs using Lagrange's method and the method of characteristics.

4. Understand Cauchy problems, local existence, and uniqueness theorems.

5. Apply Charpit's general method to solve nonlinear first-order PDEs.

Overall Learning Outcomes

1. Develop problem-solving skills in multivariate calculus and PDEs.

2. Demonstrate understanding of mathematical concepts and their applications.

3. Apply mathematical models to solve problems in physics, engineering, and other fields.

4. Analyze and interpret physical phenomena using mathematical principles.

5. Develop critical thinking and analytical skills in mathematics.

Learning Outcomes of *MATH-H-CC 8-4-TH:*

The learning outcomes of this course are:

Group Theory - II

1. Understand normal subgroups, quotient groups, and group homomorphisms.

2. Apply the correspondence theorem and isomorphism theorems.

3. Analyze automorphisms, inner automorphisms, and automorphism groups.

4. Understand external and internal direct products.

5. Apply Cauchy's theorem and converse of Lagrange's theorem.

Ring Theory - I

1. Define and identify rings, subrings, integral domains, and fields.

2. Understand properties of rings, subfields, and characteristic of a ring.

3. Analyze ideals, factor rings, and ring homomorphisms.

4. Apply isomorphism theorems, correspondence theorem, and congruence on rings.

5. Understand prime and maximal ideals.

Overall Learning Outcomes

1. Develop problem-solving skills in group theory and ring theory.

2. Demonstrate understanding of abstract algebraic structures.

3. Apply mathematical concepts to solve problems in computer science, physics, and other fields.

4. Analyze and interpret algebraic structures using mathematical principles.

5. Develop critical thinking and analytical skills in mathematics.

Learning Outcomes of *MATH-H-MC 2-4-Th:*

Same as MATH-H-MC 2-2-Th

SEMESTER V

Learning Outcomes of *MATH-H-CC 9-5-TH:*

The learning outcomes of this course are:

Group A: Probability

1. Understand probability concepts: random experiments, sample space, events, and probability axioms.

2. Apply conditional probability, independence, and Bayes' theorem.

3. Analyze random variables: discrete and continuous distributions, expectation, variance, and moments.

4. Understand multivariate random variables, joint distributions, and conditional distributions.

5. Apply Chebyshev's inequality, convergence in probability, and central limit theorem.

Group B: Statistics

1. Understand sampling distributions, point estimation, and interval estimation.
2. Apply estimation methods: maximum likelihood, unbiasedness, consistency, and sufficiency.
3. Analyze bivariate frequency distributions: correlation, covariance, and linear regression.
4. Understand confidence intervals and hypothesis testing: simple and composite hypotheses, type I and II errors.
5. Apply statistical tests: tests on the mean of a normal distribution, chi-square test for goodness of fit.

Overall Learning Outcomes

1. Develop problem-solving skills in probability and statistics.
2. Demonstrate understanding of probability concepts and statistical methods.
3. Apply mathematical and statistical techniques to real-world problems.
4. Analyze and interpret data using statistical principles.
5. Develop critical thinking and analytical skills in probability and statistics.

Learning Outcomes of *MATH-H-CC 10-5-TH:*

The learning outcomes of this course are:

Group A: Ring Theory - II

1. Understand principal ideal domains, prime elements, and irreducible elements.
2. Apply concepts of greatest common divisor (gcd) and least common multiple (lcm).
3. Analyze polynomial rings, division algorithm, and unique factorization domains.
4. Understand ring embedding, quotient fields, and regular rings.

Group B: Linear Algebra - I

1. Understand vector spaces, subspaces, linear combinations, and linear independence.
2. Apply concepts of basis, dimension, and quotient spaces.
3. Analyze linear transformations, null space, range, rank, and nullity.
4. Understand matrix representation, change of coordinate matrix, and eigenvalues.

Overall Learning Outcomes

1. Develop problem-solving skills in ring theory and linear algebra.
2. Demonstrate understanding of abstract algebraic structures.
3. Apply mathematical concepts to solve problems in computer science, physics, and other fields.
4. Analyze and interpret algebraic structures using mathematical principles.
5. Develop critical thinking and analytical skills in mathematics.

Learning Outcomes of *MATH-H-CC 11-5-TH:*

The learning outcomes of this course are:

Group A: Riemann Integration

1. Understand Riemann integration, including upper and lower Darboux sums and integrals.
2. Apply Darboux's theorem and Riemann's definition of integrability.
3. Analyze negligible sets and their relation to Riemann integrability.
4. Understand properties of Riemann integrable functions, including integrability of sums, products, and quotients.
5. Apply the fundamental theorem of integral calculus and mean value theorems.

Group B: Series of Functions

1. Understand sequence and series of functions, including pointwise and uniform convergence.
2. Apply Cauchy criterion, Weierstrass's M-test, and Dini's theorem.
3. Analyze power series, including radius of convergence, uniform and absolute convergence, and properties of sum functions.
4. Understand Fourier series, including trigonometric series, Fourier coefficients, and Dirichlet's condition of convergence.

Overall Learning Outcomes

1. Develop problem-solving skills in Riemann integration and series of functions.
2. Demonstrate understanding of mathematical concepts and their applications.
3. Apply mathematical techniques to solve problems in physics, engineering, and other fields.
4. Analyze and interpret mathematical structures using mathematical principles.
5. Develop critical thinking and analytical skills in mathematics.

Learning Outcomes of *MATH-H-CC 12-5-TH:*

The learning outcomes of this course are:

Statics-II

1. Understand friction: laws of static friction, limiting friction, and angle of friction.
2. Apply virtual work: degrees of freedom, constraints, and virtual displacement.
3. Analyze stable and unstable equilibrium: potential energy, conservative fields, and energy test of stability.
4. Understand arbitrary force systems in three dimensions: axis of a couple, resultant of couples, and reduction of a system of forces.

Dynamics of a Particle-II

1. Understand stability of nearly circular orbits and motion of a particle on a rough curve.
2. Apply expressions for components of velocity and acceleration referred to rotating axes.

3. Analyze dynamics of a system of particles: general theorems, external forces, internal forces, and conservation principles.

Dynamics of Rigid Body

1. Understand vector angular velocity and particle velocities in a rigid body.
2. Apply moments and products of inertia, principal axes, and momental ellipsoid.
3. Analyze general motion: equations of motion, angular momentum, and kinetic energy.
4. Understand motion of a rigid body in two dimensions: equations of motion, kinetic energy, and angular momentum.
5. Apply motion under impulsive forces: equation of motion, conservation of linear and angular momentum.

Overall Learning Outcomes

1. Develop problem-solving skills in mechanics.
2. Demonstrate understanding of mathematical concepts and their applications.
3. Apply mathematical techniques to solve problems in physics, engineering, and other fields.
4. Analyze and interpret physical phenomena using mathematical principles.
5. Develop critical thinking and analytical skills in mechanics.

Learning Outcomes of *MATH-H-MC 3-5-Th:*

Same as MATH-H-CC4-3-Th.