Sardar Vallabhbhai National Institute of Technology (SVNIT) Surat
Department of Mathematics
Bachelor of Technology in Mathematics and Computing (MaC)

Sr. No.	Subject	Code	Scheme L-T-P	Credits (Min.)	Notional hours of Learning (Approx.)
	Third Semester (2nd year of B.Tech. MaC)				
1	Elements of Analysis	MA201	3-1-0	4	70
2	Discrete Mathematics for Computing	MA207	3-1-0	4	70
3	Data Structures and Algorithms	MA233	3-0-2	4	85
4	Elective-I	MA2AA	3-1-0/ 3-1-0	4	70
5	Database Management Systems	MA235	3-0-2	4	85
			Total	**20**	**380**
	Fourth Semester (2nd year of B.Tech. MaC)				
1	Numerical Analysis	MA202	3-1-0	4	70
2	Computational Linear Algebra	MA206	3-1-0	4	70
3	Elementary Number Theory	MA234	3-1-0	4	70
4	Elective-II	MA2BB	3-1-0/ 3-0-2	4	70/85
5	Design and Analysis of Algorithms	MA236	3-2-0	4	85
			Total	**20**	**365/380**
6	Mathematical Software/ Mini project-I	MAV04 /	0-0-10	5	200
	Vocational Training / Professional Experience	MAP04			(20 x 10)

Sr. No.	Elective	Code	Scheme L-T-P
	Elective-I		
1	Analytical Geometry	MA251	3-1-0
2	Object Oriented Programming	MA252	3-0-2
	Elective-II		
3	Computer Networks	CS208	3-0-2
4	Computational Life Sciences	MA253	3-1-0

Subject Code:##nXX; ##: Department Identity, n: Year, XX: Subject Sequence number XX: last digit 0 (subject offered in both ODD and EVEN semesters, XX: 01 to 30 – last digit ODD and EVEN for ODD and EVEN semesters (Mandatory Core), XX: 31 to 50 (Optional Core), XX: 51 to 99 (Elective), Subjects list for Minor and Honor (M/H#1-4), Subjects list for Specialization track (#1-4)EG: Engineering Subject, SC: Science Subject (offered combinedly by departments) (SVNIT Surat)

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B.Tech. 2nd Year (MaC) Semester – III Elements of Analysis MA 201	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, the students will be able to
CO1	Discuss the convergence and divergence of sequences and series
CO2	Predict the existence of Riemann integral with their properties
CO3	Demonstrate the convergence of improper integral
CO4	Examine the uniform convergence using different tests
CO5	Develop the Fourier series in different intervals

2.	**Syllabus**	
	REAL SEQUENCES AND INFINITE SERIES	(**05 Hours**)
	Orientation of real Sequences and infinite series: Limit points of a sequence, Limits inferior and superior, Convergent sequences, Non Convergent sequences, Cauchy's general principle of convergence, Algebra of sequences, Some important theorems, Monotonic sequences. Positive terms series, Comparison test, Cauchy's root test, D'Alembert ratio test, Series with arbitrary terms.	
	THE RIEMANN INTEGRAL AND RIEMANN STIELTJES INTEGRAL	**(15 Hours)**
	Definitions and existence of the integral, Refinement of partitions, Darboux's theorem, Conditions of integrability, Integrability of the sum and difference of Integrable functions, The integral as a limit of sums, Some integrable functions, Integration and differentiation, The fundamental theorem of calculus, Mean value theorem, Integration by parts, Change of variable in an integral, Second mean value theorem, Stieltjes Integral and properties	
	VECTOR OPERATORS	**(05 Hours)**
	Green's, Gauss' & Stokes' theorem with proof.	
	IMPROPER INTEGRAL	**(06 HOURS)**
	Introduction, Integration of unbounded functions with finite limit of integration, Comparison tests for convergence of $\int_a^b f(x)dx$, Infinite range of integration, Integrand as a product of functions.	
	UNIFORM CONVERGENCE	**(08 HOURS)**
	Pointwise convergence, Uniform convergence on an interval, Tests for uniform convergence, Properties of uniformly convergent sequences and series, The Weierstrass approximation theorem.	
	FOURIER SERIES	**(06 Hours)**
	Trigonometric series, Some preliminary theorems, The main theorem, Intervals other than $[-\pi, \pi]$, Fourier Integrals.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)	

3.	**Tutorials**
1	Tutorial on convergent and monotonic sequences.
2	Tutorial on Riemann integral, Green's, Stokes' and Gauss' theorem.
3	Tutorial on integration of unbounded functions and comparison tests of convergence.
4	Tutorial on pointwise convergence, uniform convergence and Weierstrass approximation theorem.
5	Tutorial on trigonometric series.

4.	**<u>Books Recommended:</u>**
1	Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett Learning, Burlington, MA, 1st Edition, 2010
2	Andrew Browder, Mathematical Analysis: *An Introduction*, Springer, New York, 2nd Edition, 2012.
3	Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Boston, MA, 2nd Edition, 2014.
4	H. L. Royden and P. M. Fitzpatrick, Real Analysis, Pearson, New York, 4th Edition, 2010.
5	William P. Ziemer, Modern Real Analysis, Springer, New York, 2nd Edition, 2017.
	Additional Reference Book:
1	Rudin, W., *Principles of mathematical analysis* (3rd ed.). McGraw-Hill, 1976.

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B.Tech. 2nd Year (MaC) Semester – III DISCRETE MATHEMATICS AND COMPUTING MA 207	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, the students will be able to
CO1	apply knowledge of Mathematical Logic in programming
CO2	analyze the problems for developing the solution, its correctness and performance using graphs
CO3	analyze the real world problems using graph theory, relations, lattices and Boolean algebra
CO4	develop an algorithm using Asymptotic analysis
CO5	design solutions for various types of problems in different disciplines like information security, optimization, mathematical analysis

2.	<u>Syllabus</u>	
	MATHEMATICAL LOGIC AND PROGRAM VERIFICATION	**(10 Hours)**
	Propositions, logical operators and propositional algebra, Predicates and quantifiers, Interaction of quantifiers with logical operators, Logical interference & proof techniques, Formal verification of computer programs (elements of Hoare logic).	
	GRAPH THEORY	**(10 Hours)**
	Graphs, Definition and basic concepts of finite and infinite graph, Incidence and Degree, Isomorphism, Subgraph, Walk, Path & Circuits, Operations on graphs, Connected Graph, Disconnected graph and Components, Complete graph, Regular graph, Bipartite graph, Euler's graph, Hamiltonian paths and Circuits, Weighted graphs, Applications, Directed & Undirected graphs, Connectivity of graphs.	
	TREES	**(06 Hours)**
	Definition & properties of trees, Pendent vertices in a tree, Distance between two vertices, Centre, Radius and diameter of a tree, Rooted and binary trees, Representation of Algebraic structure by Binary trees, Binary search trees, Spanning trees and fundamental circuits.	
	LATTICES	**(06 Hours)**
	Definition and properties of lattice, Sublattice, Distributive and modular lattices, Complemented and bounded lattices, Complete lattices.	
	BOOLEAN ALGEBRA	**(06 Hours)**
	Introduction, Definition, Properties of Boolean algebra, Boolean variables, Boolean expression, Boolean function, Min term, Max term, Canonical forms, Switching network from Boolean expression, Karnaugh map method.	
	ASYMPTOTIC ANALYSIS	**(07 Hours)**
	Complexity analysis, Time and storage analysis, Big-O, Application to real world problems.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
		(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)

3.	**Tutorials**
1	Tutorials on Mathematical Logic and Program Verification
2	Tutorials on Graph Theory
3	Tutorials on Trees
4	Tutorials on Lattices
5	Tutorials on Boolean Algebra
6	Tutorials on Asymptotic Analysis

4.	**Books Recommended:**
1.	K. H. Rosen, Discrete Mathematics and its Applications, 8th Edition, McGraw-Hill, 2018.
2.	B. Kolman, R. C. Busby, and S. Ross, Discrete Mathematical Structure, 6th Edition, Prentice Hall Inc., 2021.
3.	Kenneth H. Rosen, Discrete Mathematics and Its Applications, McGraw-Hill Education, New York, 8th Edition, 2019.
4.	Lewis, H., & Zax, R., *Essential Discrete Mathematics for Computer Science*. Princeton University Press, 2019.
5.	Oscar Levin, Discrete Mathematics: An Open Introduction, CreateSpace Independent Publishing Platform, 4th Edition, 2023.

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B.TECH. 2nd Year (MaC) Semester – III DATA STRUCTURES AND ALGORITHMS MA 233	Scheme	L	T	P	Credit
		3	0	2	04

1.	Course Outcomes (COs): At the end of the course, the students will be able to
CO1	Understanding Data Structures and Abstract Data Types
CO2	Implementing and Applying Linear Data Structures
CO3	Analyzing Sorting and Searching Techniques
CO4	Manipulating Trees and Multiway Trees
CO5	Applying Graph Algorithms

2.	**Syllabus**	
	INTRODUCTION TO DATA STRUCTURES	**(03 Hours)**
	Information and meaning, Abstract data types, Internal representation of primitive data structures, Arrays, Strings, Pointers.	
	LINEAR LISTS	**(06 Hours)**
	Sequential and linked representations of linear lists, Comparison of insertion, Deletion and search operations for sequential and linked lists, Doubly linked lists, Circular lists, Lists in Standard Template Library (STL), Applications of lists.	
	STACKS	**(06 Hours)**
	Sequential and linked implementations, Representative applications such as Recursion, Expression evaluation viz., Infix, Prefix and Postfix, Parenthesis matching, Towers of Hanoi, Wire routing in a circuit, Finding path in a maze.	
	QUEUES	**(06 Hours)**
	Operations of queues, Circular Queue, Priority Queue, Dequeue, Applications of queues, Simulation of time-sharing operating systems, Continuous network monitoring system, etc.	
	SORTING AND SEARCHING	**(05 Hours)**
	Sorting methods, Bubble sort, Selection sort, Quick sort, Radix sort, Bucket sort, Dictionaries, Hashing, Analysis of collision resolution techniques, Searching methods, Linear search, Binary search, Character strings and different string operations.	
	TREES	**(08 Hours)**
	Binary trees and their properties, Terminology, Sequential and linked implementations, Tree traversal methods and algorithms, Complete Binary trees, General trees, AVL trees, Threaded trees, Arithmetic expression evaluation, Infix-prefix-postfix notation conversion, Heaps as priority queues, Heap implementation, Insertion and deletion operations, Heapsort, Heaps in Huffman coding, Tournament trees, Bin packing.	

	MULTIWAY TREES	**(04 Hours)**
	Issues in large dictionaries, M-way search trees, B-trees, Search, insert and delete operations, Height of B-tree, 2-3 trees, Sets and multisets in STL.	
	GRAPHS	**(07 Hours)**
	Definition, Terminology, Directed and undirected graphs, Properties, Connectivity in graphs, Applications, Adjacency matrix and linked adjacency chains, Graph traversal, Breadth first and depth first traversal, Spanning trees, Shortest path and transitive Closure, Activity networks, Topological Sort and critical paths.	
	Practicals will be based on the coverage of the above topics separately.	**(30 Hours)**
		(Total Contact periods / Hrs.: 45 Hrs. + 30 Hrs. = 75 Hrs.)

3.	**Practicals**
1	Implementation of Array and its applications
2	Implementation of Stack and its applications
3	Implementation of Queue and its applications
4	Implementation of Link List and its applications
5	Implementation of Trees and its applications
6	Implementation of Graph and its applications
7	Implementation of Hashing functions and collision resolution techniques
8	Mini Project

4.	**Books Recommended:**
1.	Robert Sedgewick and Kevin Wayne, Algorithms, Addison-Wesley Professional, Boston, 4th Edition, 2011.
2.	Aditya Bhargava, Grokking Algorithms: An Illustrated Guide for Programmers and Other Curious People, Manning Publications, Shelter Island, NY, 1st Edition, 2016.
3.	Narasimha Karumanchi, Data Structures and Algorithms Made Easy, Career Monk Publications, India, 5th Edition, 2016.
4.	T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, Introduction to Algorithms, 4th Edition, MIT Press, 2022.
5.	Michael T. Goodrich, Roberto Tamassia, and Michael H. Goldwasser, Data Structures and Algorithms in Python, Wiley, Hoboken, NJ, 1st Edition, 2013.

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B.TECH. 2nd Year (MaC) Semester – III Elective-I Analytical Geometry MA 251	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, the students will be able to
CO1	demonstrate the fundamentals of analytical geometry in Cartesian and polar coordinates
CO2	discuss the equation of straight line in different forms and related properties
CO3	solve the problems related to plane and sphere
CO4	evaluate the equation of cone and cylinder and their tangent plane
CO5	elaborate the equations and other properties related to plan section and conicoids

2.	**Syllabus**	
	ORIENTATION OF COORDINATE GEOMETRY	**(08 Hours)**
	Distance between two points, Coordinates of a point which divides the line joining the given points in a given ratio, Equation of surfaces, Cylindrical coordinates, Polar coordinates, Angle between two lines, Direction cosines of a line, Direction ratios of a line, Projections, Projection of a line segment.	
	STRAIGHT LINE	**(09 Hours)**
	General equation of straight line, Equations of a line in symmetrical form, Reduction of general equation of a line into symmetrical form, Angles between two lines, Angle between line and plane, Line intersecting two given lines, Locus of a line, Distance of a point from a line, Shortest distance between two lines, Equations of two skew lines in simplified form, Intersection of three planes.	
	PLANE AND SPHERE	**(09 Hours)**
	General equation of a plane, Normal form of the equation of a plane, Projection of a segment, Angles between two planes, Equation of a plane in various forms, Length of perpendicular from a point to a plane, General equation of a plane passing through the line of intersection of two planes, General equation of sphere, Equation of sphere passing through four points, Sphere on the join of two points as diameter, Intersection of two sphere, Intersection of sphere and plane, Intersection of sphere and line, Angle of intersection of two sphere, Orthogonal sphere, Radical sphere.	
	CYLINDER AND CONE	**(10 HOURS)**
	Equation of a cylinder, Right circular cylinder and its equation, Interpretation of equations, Equation of tangent plane to a given cylinder, Cone and its equation, Cone with vertex at origin, Right circular cone, Condition for general equation of second degree to represent a cone, Tangent plane to a cone and condition of tangency, Reciprocal cone, Cone with three mutually perpendicular generators, Number of mutually perpendicular generators, Intersection of a plane through the vertex and a cone.	

	PLANE SECTION AND CONICOIDS	**(09 HOURS)**
	Some standard equation of central conicoid, Diametral planes and principal planes, Tangent lines and tangent plane at a point, Condition of tangency of a plane, Section with a given center, Locus of the mid-points of a system of parallel chords, Polar plane, Polar lines, Enveloping cone, Classification of central conicoid, Normal to an ellipsoid, Conjugate diametral plane and diameters of ellipsoid, Paraboloids: Equation, Classification and Properties, Conicoid: General equation and examples.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)	

3.	**Tutorials**
1	Tutorials will be based on distance, equation of surfaces, direction cosines, direction ratios and projection.
2	Tutorials will be based on equation of straight line, angles between two lines and intersection of three planes.
3	Tutorials will be based on equation of planes, equation of sphere and their intersection.
4	Tutorials will be based on equation of cylinder, equation of cone and mutually perpendicular generators.
5	Tutorials will be based on equation of cylinder, equation of cone and mutually perpendicular generators.

4.	**Books Recommended:**
1.	Tim Hill, Essential Geometry with Analytic Geometry: A Self-Teaching Guide, CreateSpace Independent Publishing Platform, 1st Edition, 2020.
2.	Joan Horvath and Rich Cameron, Make: Trigonometry: Build Your Way from Triangles to Analytic Geometry, Maker Media, 1st Edition, 2020
3.	Ruslan Sharipov, Course of Analytical Geometry, Self-published, 1st Edition, 2011.
4.	Alfred S. Posamentier and Ingmar Lehmann, The Secrets of Triangles: A Mathematical Journey, Prometheus Books, 1st Edition, 2012.
5.	A. R. Vasishtha, Krishna's Textbook of Analytical Geometry, Krishna Prakashan Media, 21st Edition, 2021.

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B.TECH. 2nd Year (MaC) Semester – III **Elective-I** **Object Oriented Programming** **MA 252**	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**0**	**2**	**04**

1. Course Outcomes (COs): **At the end of the course, students will be able to**	
CO1	acquire knowledge of object oriented programming.
CO2	apply the knowledge of object oriented concepts to solve the real world problems.
CO3	analyse object oriented concepts to solve the problem efficiently.
CO4	evaluate the object oriented features' suitability for the implementation of the problem.
CO5	design and implement the efficient object oriented program using various object oriented concepts.

2.	**Syllabus**	
	Introduction	**(08 Hours)**
	High Level Language, Difference between Procedure Oriented and Object Oriented Approach; Characteristics of Object-Oriented Languages Object Oriented Concepts: Objects, Classes, Principals like Abstraction, Encapsulation, Inheritance and Polymorphism; Dynamic Binding, Message Passing;, Types of Operators, Operator precedence and associativity, Data type conversions; Selection and Loops	
	Classes and Objects	**(09 Hours)**
	Abstract data types, Object and classes, attributes, methods, Class declaration, Local Class and Global Class, State identity and behavior of an object, Local Object and Global Object, Scope resolution operator, Friend Functions, Inline functions, Constructors and destructors, instantiation of objects, Types of Constructors, Static Class Data, Array of Objects, Constant member functions and Objects, Memory management Operators.	
	Inheritance	**(06 Hours)**
	Inheritance, Types of Inheritance, access modes – public, private & protected, Abstract Classes, Ambiguity resolution using scope resolution operator and Virtual base class, Aggregation, composition vs. classification hierarchies, Overriding inheritance methods, Constructors in derived classes, Nesting of Classes.	
	Polymorphism	**(06 Hours)**
	Polymorphism, Type of Polymorphism – Compile time and runtime, Function Overloading, Operator Overloading (Unary and Binary) Polymorphism by parameter, Pointer to objects, this pointer, Virtual Functions, pure virtual functions, Late Binding, Abstract Classes.	
	Dynamic memory management	**(04 Hours)**
	Dynamic memory management, new and delete operators, object copying, copy constructor, assignment operator, virtual destructor	

	Strings, Files and Exception Handling	**(04 Hours)**
	Manipulating strings, Streams and files handling, formatted and Unformatted Input output. Exception handling: Try, throw, and catch, exceptions and derived classes, function exception declaration, unexpected exceptions, exception when handling exceptions, resource capture and release.	
	Standard Template Library	**(08 Hours)**
	Standard Template Library, Overview of Standard Template Library, Containers, Algorithms, Iterators, Other STL Elements, The Container Classes, General Theory of Operation, Vectors, Usage of Template Library for the Implementation of Data Structure.	
	Practical will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact periods / Hrs.: 45 Hrs. + 30 Hrs. = 75 Hrs.)	

3.	**Practicals using C++/JAVA:**
1.	Creation of objects in programs.
2.	Experiments with private, public member variables and functions and friend functions.
3.	Experiments for the usage of constructors and destructors.
4.	Experiments for the working of operator overloading.
5.	Experiments with abstract classes, interfaces and inheritance to access objects.
6.	Experiments with polymorphism and virtual functions.
7.	Experiments for strings manipulation.
8.	Experiments on file handling.
9.	Implementing common data structures, such as trees, lists and hash tables.
10.	To deal with runtime errors using exception handling mechanism.
11.	Implementation of mini project using object oriented concepts.

4.	**Books Recommended:**
1.	E. Balagurusamy, Object Oriented Programming with C++, 8th Edition, McGraw Hill, 2020.
2.	E. Balagurusamy, Programming with JAVA, 7th Edition, McGraw Hill, 2023.
3.	Mark Priestley, Practical Object-Oriented Design with UML, McGraw-Hill Education, New York, 2nd Edition, 2012.
4.	Dusty Phillips, Python 3 Object-Oriented Programming, Packt Publishing, Birmingham, 2nd Edition, 2015.
5.	Naughton P. and Schildt H., Java2: Complete Reference, Eighth Edition, Tata McGraw Hill, 2011.

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B.TECH. 2nd Year (MaC) Semester – III DATABASE MANAGEMENT SYSTEMS MA235	Scheme	L	T	P	Credit
		3	0	2	04

1.	**Course Outcomes (COs):** **At the end of the course, the students will be able to**
CO1	understand different database models and query languages to manage the data for given real life application scenario.
CO2	apply the concept of lock management to handle transactions and concurrent user access.
CO3	analyse and evaluate the database design to produce efficient and optimum solution.
CO4	analyse and evaluate the query performance and design the optimum query solution.
CO5	design, populate, and document a normalized database that meets business requirements using industry standards for the given problem.

2.	**Syllabus**	
	INTRODUCTORY CONCEPTS OF DBMS	**(03 Hours)**
	Introduction, Applications of DBMS, Purpose of Database, Data Independence, Database System Architecture, Data Abstraction, Database users and DBA.	
	ENTITY RELATIONSHIP MODEL	**(04 Hours)**
	Fundamental Concepts, Design Process, Constraints, Keys, Design Issues, E-R Diagrams, Attribute Types, Mapping Cardinality, Types of Relationship, Weak/Strong Entity Sets, Extended E-R Features – Generalization, Specialization, Aggregation.	
	RELATIONAL MODELS	**(04 Hours)**
	Structure of Relational Databases, Domains, Relations, Mapping of ER Model to Relational Model, Relational Algebra – Fundamentals, Operators and Syntax, Relational Algebra Queries, Tuple Relational Calculus.	
	RELATIONAL DATABASE DESIGN	**(06 Hours)**
	Functional Dependency – Definition, Trivial and Non-trivial FD, Closure of FD Set, Closure of Attributes, Irreducible Set of FD, Normalization – 1Nf, 2NF, 3NF, Decomposition using FD- Dependency Preservation, BCNF, Multi- Valued Dependency, 4NF, Join Dependency and 5NF.	
	QUERY PROCESSING AND OPTIMIZATION	**(05 Hours)**
	Overview of Query Processing, Measures of Query Cost, Select Operation, Sorting, Join Operation, Other Operations, Evaluation of Expressions, Overview of Query Optimization, Transformation of Relational, Expressions, Estimating Statistics of Expression Results, Choice of Evaluation Plans, Materialized Views, Advanced Topics in Query Optimization..	

	QUERY PROCESSING AND OPTIMIZATION	**(04 Hours)**
	Overview of Query Processing, Measures of Query Cost, Select Operation, Sorting, Join Operation, Other Operations, Evaluation of Expressions, Overview of Query Optimization, Transformation of Relational, Expressions, Estimating Statistics of Expression Results, Choice of Evaluation Plans, Materialized Views, Advanced Topics in Query Optimization.	
	TRANSACTION MANAGEMENT	**(08 Hours)**
	Transaction Concepts, Properties of Transactions, Serializability of Transactions, Testing for Serializability, Concurrent Executions of Transactions and Related Problems, Locking Mechanism, Solution to Concurrency Related Problems, Two-phase Locking Protocol, Deadlock, Isolation, Intent Locking, System Recovery, Recovery and Atomicity, Log-based Recovery.	
	SQL CONCEPT	**(04 Hours)**
	Basics of SQL, DDL,DML, DCL, Structure – Creation/Alteration, Defining Constraints – Primary Key, Foreign Key, Unique, Not Null, Check, IN Operator.	
	PL-SQL CONCEPT	**(02 Hours)**
	Cursors, Stored Procedures, Stored Function, Database Triggers.	
	ADVANCED TOPICS	**(05 Hours)**
	Data Security: Introduction, Discretionary Access Control, Mandatory Access Control, Data Encryption, Semi Structured Data and XML, Object Oriented and Object Relational DBMS, Distributed DBMS, NOSQL DBMS.	
	Practical will be based on the coverage of the above topics separately.	**(30 Hours)**
		(Total Contact periods / Hrs.: 45 Hrs. + 30 Hrs. = 75 Hrs.)

3.	**Practical**
1	Implementation for Physical data storage (Sequential, Index Sequential.)
2	Practicing DDL and DML Queries for database creation and managing the data
3	Develop a Database system for the real-life application scenario by managing the storage constrains
4	Practicing PL/SQL with the designed databases
5	Design considering Transaction management and concurrency control
6	Design of ER model-based example
7	Design of Relational model-based example
8	Design of Normalized form of database

5.	**Books Recommended:**
1	Ramez Elmasri and Shamkant B. Navathe, Fundamentals of Database Systems, Pearson, Boston, 7th Edition, 2016.
2	Abraham Silberschatz, Henry F. Korth, and S. Sudarshan, Database System Concepts, McGraw-Hill Education, New York, 7th Edition, 2019.
3	Raghu Ramakrishnan and Johannes Gehrke, Database Management Systems, McGraw-Hill Education, New York, 3rd Edition, 2014.
4	Carlos Coronel and Steven Morris, Database Systems: Design, Implementation, & Management, Cengage Learning, Boston, 13th Edition, 2018.
5	Mark L. Gillenson, Fundamentals of Database Management Systems, Wiley, Hoboken, NJ, 3rd Edition, 2022.

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B.TECH. 2nd Year (MaC) Semester – IV **NUMERICAL ANALYSIS** **MA202**	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**1**	**0**	**04**

1.	**Course Outcomes (COs):** **At the end of the course, the students will be able to**
CO1	design an algorithm to solve a mathematical problem numerically
CO2	analyze an algorithm's accuracy, efficiency and convergence properties
CO3	develop a computer code for the designed algorithm
CO4	analyze classical techniques and recognize common pitfalls in numerical analysis
CO5	solve initial value problems using computational methods

2.	**<u>Syllabus</u>**	
	PRELIMINARIES OF COMPUTING	**(03 Hours)**
	Errors, Types of errors, Propagation of Error, Floating point arithmetic, Approximation using Taylor's series.	
	SOLUTION OF NONLINEAR EQUATIONS	**(08 Hours)**
	Bisection Method, Methods of false position, Newton's method, Modified Newton's method, Fixed point iterative method, Newton's and fixed-point iterative method for system of nonlinear equations. Roots of polynomials, Error and convergence analysis of these methods.	
	SOLUTION OF SYSTEM OF LINEAR EQUATIONS	**(08 Hours)**
	Direct Methods: Gauss elimination with pivoting, LU decomposition method, Cholesky decomposition method, Error analysis for direct methods, Iterative methods: Jacobi, Gauss Seidel method, SOR method, Vector and matrix norm, Convergence of iterative methods, Eigenvalue problems: Jacobi's and Power method.	
	INTERPOLATION	**(12 Hours)**
	Finite difference operators, Divided difference operators, Relation between difference operators, Application of difference operators, Polynomial Interpolation, Existence and uniqueness of interpolating polynomials, Lagrange and Newton's interpolation, Newton's forward and backward difference formula, Error in interpolation.	

	DIFFERENTIATION AND INTEGRATION	**(07 Hours)**
	Numerical differentiation: Methods based on interpolation and finite differences, Error in approximation, Order of approximation, Numerical Integration: Quadrature formula, Newton Cotes Methods, Trapezoidal and Simpson's rules with error analysis. Gauss quadrature methods with error analysis.	
	INITIAL VALUE PROBLEMS (ODE)	**(07 Hours)**
	Picard's method, Taylor's series method, Euler and Runge-Kutta methods for initial value problems of order one and higher and system of first order ODEs with error analysis.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
	(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)	

3.	**Tutorials**
1	Tutorials on nonlinear equations.
2	Tutorials on system of nonlinear equations.
3	Tutorials on system of linear equations using direct methods.
4	Tutorials on system of linear equations using indirect methods.
5	Tutorials on the eigenvalue of a matrix.
6	Tutorials on interpolating arbitrary spaced and equally spaced data.
7	Tutorials on approximate the derivative numerically.
8	Tutorials on integrate a function numerically.
9	Tutorials to solve the initial value problems of order one and more.
10	Tutorials on system of first order ODEs.

4.	**Books Recommended:**
1	Richard L. Burden, J. Douglas Faires, and Annette M. Burden, Numerical Analysis, Cengage Learning, Boston, MA, 10th Edition, 2015.
2	David Kincaid and Ward Cheney, Numerical Analysis: Mathematics of Scientific Computing, American Mathematical Society, Providence, RI, 3rd Edition, 2010.
3	M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods: For Scientific and Engineering Computation, 6th Edition, New Age International Publishers, 2014.
4	S.S. Sastri, Introductory Methods of Numerical Analysis, 5th Edition, Eastern Economy Edition, 2012.
5	Timothy Sauer, Numerical Analysis, Pearson, Boston, MA, 3rd Edition, 2017.

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B.TECH. 2nd Year (MaC) Semester – IV **COMPUTATIONAL LINEAR ALGEBRA** **MA206**	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**1**	**0**	**04**

1.	**Course Outcomes (COs):**
CO1	evaluate the solution of system of linear equation through elimination and decomposition procedure along with the numerical solutions
CO2	determine the basis and dimension of vector spaces and subspaces
CO3	discuss the matrix representation of a linear transformation given bases of the relevant vector spaces
CO4	adapt the knowledge of eigenvalues and eigenvectors for matrix diagonalization
CO5	interpret the applications of linear algebra and special matrices

2.	**<u>Syllabus</u>**	
	Matrices	**(05 Hours)**
	Properties of matrices, Non-singular Matrices, Reduced Row-Echelon form, Special Matrices, Consistency and Solution of system of linear equations.	
	Stability of Algorithms	**(07 Hours)**
	Floating points arithmetic, Stability of algorithms, conditioning of a problems, perturbation analysis.	
	Vector Spaces	**(06 Hours)**
	Fields, Vector spaces over a field, Subspaces, Linear Independence and Dependence, Coordinates, Bases and Dimension.	
	LINEAR TRANSFORMATIONS	**(06 Hours)**
	Rank Nullity Theorem, Duality and transpose, Isomorphism, Matrix representation of linear transformation, Change of basis, Similar matrices, Linear functional and Dual Space.	
	INNER PRODUCT SPACES	**(08 Hours)**
	Cauchy-Schwarz's inequality, Gram-Schmidt orthonormalization, Orthonormal basis, Orthogonal projection, Projection theorem, Fundamental subspaces and their relations	
	DIAGONALIZATION	**(05 Hours)**
	Eigenvalues and eigenvectors, Characteristic polynomials, Minimal polynomials, Cayley-Hamilton theorem, Diagonalizability, Invariant subspaces, numerical eigenvalue problems	

	SOME APPLICATIONS	**(08 HOURS)**
	QR and SVD decompositions, Least square solutions, Least square fittings, Pseudo-inverses, Rayleigh quotients, Special matrices and their properties.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
		(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)

3.	**Tutorials**
1	Tutorials on matrices and system of equations.
2	Tutorials on fields, subspaces, basis and dimension.
3	Tutorials on linear transformations, gram Schmidt orthonormalization and projection theorem.
4	Tutorials on eigen values, eigen vectors, characteristic polynomials and canonical form.
5	Tutorials on Lagrange interpolation, QR and SVD decomposition, pseudo inverses and special matrices.

4.	**Books Recommended:**
1	Michael W. Artin, Algebra, Pearson, Boston, 2nd Edition, 2011.
2	Serge Lang, Linear Algebra, Springer, New York, 3rd Edition, 2012.
3	K. Hoffman and R. Kunze, Linear Algebra, Pearson Publication, 2018
4	S. Lang, Applied Linear Algebra (Undergraduate Texts in Mathematics), Springer Nature Switzerland AG; 2nd ed. 2018.
5	Melvin Hausner, A Vector Space Approach to Geometry, Dover Publications Inc.; 2018.

5.	**Additional Books Recommended:**
1	H. E. Rose, Linear Algebra: A Pure Mathematical Approach, Birkhauser, 2002.
2	David C. Lay, Steven R. Lay, and Judi J. McDonald, Linear Algebra and Its Applications, Pearson, Boston, 5th Edition, 2015.
3	G. Strang, Linear Algebra and its Applications, 4th edition, Cengage Learning, 2007.
4	G. William, Linear Algebra with Applications, 9th Revised Edition, Jones and Bartlett Publishers Inc., 2017.

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B.TECH. 2nd Year (MaC) Semester – IV **ELEMENTARY NUMBER THEORY** **MA234**	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**1**	**0**	**04**

1.	**Course Outcomes (COs):** **At the end of the course, the students will be able to**
CO1	explain congruence relations and number theoretic functions
CO2	demonstrate Fermat's theorem and its applications
CO3	solve Diophantine equations
CO4	elaborate primitive roots and quadratic reciprocity
CO5	adapt the knowledge of various techniques in cryptography

2.	**Syllabus**	
	INTRODUCTION	**(07 Hours)**
	Divisibility, Greatest Common Divisor (GCD), Euclidean Algorithm, Primes and their elementary properties, Fundamental theorem of Arithmetic.	
	CONGRUENCE RELATION	**(08 Hours)**
	Congruence and their Basic properties, Chinese Remainder Theorem, Euler's phi-function, Fermat's Little Theorem, Wilson's Theorem, Euler's theorem.	
	NUMBER THEORETIC FUNCTIONS	**(12 Hours)**
	Greatest integer function, Arithmetic functions, Mobius inversion formula, Fibonacci numbers, Representation of an integer as sum of two and four squares, Diophantine Equations: $ax + by = c$, $x^2 + y^2 = z^2$ and $x^4 + y^4 = z^4$.	
	PRIMITIVE ROOTS, INDICES AND RESIDUES	**(12 Hours)**
	Order of an integer modulo n, Primitive roots for primes, Theory of indices, Residue classes, Quadratic residues, Legendre symbol, Gauss's Lemma about Legendre symbol, Law of quadratic reciprocity, Jacobi symbol.	
	INTRODUCTION TO CRYPTOGRAPHY	**(06Hours)**
	Basic definitions of plaintext, ciphertext, cipher, enciphering (encrypting), deciphering (decrypting), The Caesar cipher, Monoalphabetic and Poly alphabetic ciphers, Nonalphabetic ciphers, Exponential cryptosystem, Applications of Euler's theorem in cryptography, Introduction to public-key cryptography and RSA cryptosystems.	
	Tutorials will be based on the coverage of the above topics separately.	**(15 Hours)**
		(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)

3.	**Tutorials**
1	Tutorials on divisibility, GCD, Euclidean Algorithm.
2	Tutorials on primes and their elementary properties, fundamental theorem of Arithmetic.
3	Tutorials on congruence relation
4	Tutorials on number theoretic functions.
5	Tutorials on Diophantine equations.
6	Tutorials On Primitive roots, indices and residues.
7	Tutorials on The Caesar cipher, Monoalphabetic and Poly alphabetic ciphers, Nonalphabetic ciphers, Exponential cryptosystem.
8	Tutorials on exponential cryptosystem, applications of Euler's theorem in cryptography.
9	Tutorials on public-key cryptography and RSA cryptosystems.

4.	**Books Recommended:**
1	James S. Kraft and Lawrence C. Washington, An Introduction to Number Theory with Cryptography, 2nd Edition, CRC Press, 2022.
2	Kenneth H. Rosen, Elementary Number Theory and Its Applications, Pearson, Boston, 6th Edition, 2011.
3	David M. Burton, Elementary Number Theory, Pearson, Boston, 8th Edition, 2018.
4	Gove Effinger, Elementary Number Theory, CRC Press, Boca Raton, 1st Edition, 2021.
5	Michael Mildorf, Elementary Number Theory, Springer, Cham, 2nd Edition, 2018.

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B.TECH. 2nd Year (MaC) Semester – IV Elective-II Computational Life Sciences MA 253	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**1**	**0**	**04**

1.	**Course Outcomes (COs):** **At the end of the course, the students will be able to**
CO1	exhibit enhanced knowledge of evolution theory
CO2	assess biological inferences that depend on population genetics
CO3	demonstrate knowledge of biological systems, microbial population and epidemics
CO4	utilize the concepts of Mathematical modeling like evolutionary games theory, statistics, numerical methods etc. in Biology
CO5	apply biological mechanisms of evolution, epidemics, genetics etc. in invasion analysis and technology

2	**Syllabus**	
	THEORY OF EVOLUTION	**(08 Hours)**
	Evolution of life: Origin of Life, Structure and types of cells, Cell organelles, Biomolecules of cell, Molecular Sequences: Nucleotide and protein, Sequence comparisons: Dynamic programming, Phylogenetic Analysis	
	POPULATION GENETICS	**(07 Hours)**
	Mendelian genetics, Inheritance models, probability distributions in genetics, Linkage, Selection and Mutation	
	DIFFUSION IN BIOLOGICAL SYSTEMS	**(07 Hours)**
	Diffusion in biology: Constructing diffusion models, Biomass Reaction diffusion models, Bioheat Transfer models	
	MICROBIAL POPULATION MODELS	**(08 Hours)**
	Introduction to Microbiology, Microbial taxonomy: Microbial kinetics, Microbial growth in a Chemostat, Growth of microbial populations, stability, competition, Commensalism, Mutualism, Predation and mutation	
	EPIDEMIC MODELS	**(08 Hours)**
	Deterministic epidemic models, epidemic control, Stochastic epidemic models, Epidemic Networks: Spread of disease in contact networks	

	EVOLUTIONARY INVASION ANALYSIS	**(07 Hours)**
	Introduction to Game Theory, Evolutionary Game theory, Concept of evolutionary stability, Adaptive dynamics, invasion analysis.	
	Tutorials will be based on the coverage of the above topics separately	**(15 Hours)**
(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)		

3.	**Tutorials**
1	Sequence Analysis, dynamic programming and Phylogenetic analysis
2	Probability distributions in genetics, models of Inheritance
3	Reaction Diffusion models in biology, Bioheat transfer models
4	Growth of microbial populations**,** stability, equilibrium, competition
5	Epidemic models under various conditions, Spread of disease in contact networks,
6	Games theory, evolutionary games theory, stability, equilibrium, Invasion analysis

4.	**Books Recommended:**
1	Jens Dörpinghaus, Vera Weil, Sebastian Schaaf, and Alexander Apke, Computational Life Sciences: Data Engineering and Data Mining for Life Sciences, Springer, Cham, 1st Edition, 2023.
2	Basant K. Tiwary, Bioinformatics and Computational Biology: A Primer for Biologists, Springer, Singapore, 1st Edition, 2021.
3	V. Subramanian Thangarasu, Ganesan Balakrishnan, and T. Sivaraman, Marvels of Artificial and Computational Intelligence in Life Sciences, Bentham Science Publishers, Sharjah, 1st Edition, 2023.
4	J.N. Kapur, Mathematical Models in Biology and Medicine, Affiliated East West Press Pvt. Ltd, 2020.
5	C. C. Chatterjee, Human Physiology, 13th revised Edition, Vol 1 & 2, CBS Publisher, 2020.

5.	**Additional Reference Book:**
1	B. K. Hall, Evolution, Principles and Processes, Jones & Bartlett, 2011.
2	O. A. Hougen, K. M. Watson and R. A. Ragatz, Chemical Process Principles Part-I: Material and Energy Balances, CBS Publishers New Delhi, 2nd Edition, 2004.
3	D. Baxevanis, and B. F. F. Ouellette, Bioinformatics – A Practical Guide to the Analysis of Genes and Proteins, 2nd Edition, John Wiley and Sons Inc., 2001.
4	B. Bernd, K. Juergen, S. Lewi, Complex Population Dynamics: Nonlinear Modeling in Ecology, Epidemiology and Genetics, World Scientific Publishing Co. Pvt. Ltd., 2007.

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B.TECH. 2nd Year (MaC) Semester – IV **Elective-II** **Computer Networks** **CS208**	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**0**	**2**	**04**

1.	**Course Outcomes (COs): At the end of the course, the students will be able to**
CO1	understand computer network models and services offered at different layers of network protocol stack.
CO2	apply knowledge of data communication, data transmission techniques using various transmission media to deliver error free data and communicate with multiple nodes.
CO3	analyse various routing methods to identify effective routing protocols.
CO4	evaluate network performance by means of transport and flow control protocols, Congestion Control protocols and Quality of services.
CO5	create a computer network application using modern network tools and simulation software.

2.	**Syllabus**	
	Introduction	**(07 Hours)**
	Overview of computer networks and data communication, Computer networking protocols and standards, Types of computer networks, Network topology, Protocol hierarchies and design issues, Interfaces and services, Networking devices, OSI and TCP/IP reference models.	
	PHYSICAL LAYER	**(07 Hours)**
	Physical layer design issues, Data transmission techniques, Multiplexing, Transmission media, Asynchronous communication, Wireless transmission, ISDN, ATM, Cellular radio, Switching techniques and issues.	
	MEDIUM ACCESS CONTROL LAYER	**(08 Hours)**
	MAC layer design issues, Channel allocation methods, Multiple access protocols ALOHA, CSMA, CSMA/CD protocols, Collision free protocols, Limited contention Protocols, LAN Architectures, IEEE -802 standards, Ethernet (CSMA/CD), Token bus, Token ring, DQDB, FDDI, Bridges and recent developments.	
	NETWORK LAYER	**(07 Hours)**
	Network layer design issues, Routing algorithms and protocols, Congestion control algorithms and QoS, Internetworking, Addressing, N/W layer protocols and recent developments.	

	TRANSPORT LAYER	**(08 Hours)**
	Transport layer design issues, Transport services, Sockets, Addressing, Connection establishment, Connection release, Flow control and buffering, Multiplexing, Transport layer protocols, Real Time Transport Protocol (RTP), Stream Control Transmission Protocol (SCTP), Congestion control, QoS and Recent developments, Virtualization, Network Functions Virtualization (NFV), Software defined networks.	
	APPLICATION LAYER	**(08 Hours)**
	Client server model, Domain Name System (DNS), Hyper Text Transfer Protocol (HTTP), Email: SMTP, MIME, POP3, Webmail, FTP, TELNET, Dynamic Host Control Protocol (DHCP), Simple Network Management Protocol (SNMP) and recent developments.	
	Tutorials will be based on the coverage of the above topics separately.	**(30 Hours)**
	(Total Contact periods / Hrs.: 45 Hrs. + 30 Hrs. = 75 Hrs.)	

3.	**Practical**
1	Study network configuration commands and computer network setup.
2	Implementation of different Data Link and MAC Layer protocols.
3	Implementation of different Network Layer protocols.
4	Implementation of different Transport and Application Layer protocols.
5	Design and configure a network systems using modern network simulator softwares.
6	Implementation of Secured Socket Layer protocol.
7	Implementation of ICMP based message transmission over network.
8	Implementation of SMTP protocol for mail transfer.

4.	**Books Recommended:**
1	W. Stalling, Data and Computer Communication, 10^{th} Edition, Pearson India, 2017.
2	B. Forouzan, Data Communication and Networking, 5^{th} Edition, McGraw Hill, 2017.
3	D. E. Comer, Internet working with TCP/IP Volume – I, 6^{th} Edition, Pearson India, 2015.
4	A. S. Tanenbaum, Computer Network, 5^{th} Edition, Pearson India, 2013.
5	W. R. Stevens, TCP/IP Illustrated Volume - I, 2^{nd} Edition, Addison Wesley, 2011.

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B.TECH. 2nd Year (MaC) Semester – IV Design and Analysis of Algorithms MA236	Scheme	L	T	P	Credit
		3	1	0	04

1.	Course Outcomes (COs): At the end of the course, students will be able to
CO1	demonstrate knowledge of the role of algorithms in computing, including insertion sorting and various sorting techniques.
CO2	perform mathematical, empirical, and asymptotic analysis of algorithms, including solving recurrence relations and employing proof techniques.
CO3	solve complex problems using dynamic programming and greedy algorithms, such as the knapsack problem, longest common subsequence, and matrix multiplication.
CO4	apply searching algorithms like backtracking and branch & bound, analyse their complexity, and solve problems involving matrix operations and online algorithms.
CO5	understand the concepts of NP-completeness and approximation algorithms, including vertex-cover, traveling salesperson, and subset-sum problems.

2.	Syllabus	
	Introduction	**(08 Hours)**
	The role of algorithms in computing; Insertion sorting; Mathematical, Empirical and Asymptotic Analysis; Recurrence Relations and Solving Recurrences; Mathematical Proof Techniques; Probabilistic Analysis.	
	Divide and Conquer Approach	**(08 Hours)**
	Sorting & Order Statistics: Heapsort, Quicksort, Sorting in Linear time, Median and order Statistics, Divide and Conquer Technique: Multiplying Square Matrices, Strassen's algorithm, Various Comparison Sorts, Analysis of the Worst-Case and the Best-Cases, Randomized Sorting Algorithms, Lower Bound Sorting, Non-comparison-based Sorts, Medians and Order Statistics, Min-Max Problem, Polynomial Multiplication.	
	Dynamic Programming	**(08 Hours)**
	Motivation, Rod Cutting, Matrix Multiplication Problem, Greedy Algorithms, Huffman codes, Offline Coaching, Amortized Analysis: Accounting method, the potential method, dynamic tables, Coin Changing Problem, Longest Common Subsequence, 0/1 Knapsack problem, All-pairs Shortest Path Problems, Elements of Dynamic Programming, Dynamic Programming Control Abstraction, Longest common subsequence, Optimal Binary Search Tree.	

	Searching Algorithms	**(07 Hours)**
	Backtracking, N-Queens Problem, Sum of Subset Problem, Complexity Analysis, Branch & Bound, Least Cost Branch & Bound (LCBB), LCBB Complexity Analysis, Parallel Algorithm, Online Algorithms: Waiting for an elevator, Online Coaching, Matrix Operations: Solving system of linear equations, inverting matrices.	
	Number Theoretic Algorithms	**(07 Hours)**
	Number Theoretic Notions, GCD, Modular Arithmetic, Chinese Remainder Theorem, Generators, Cyclic Groups, Galois Fields, Applications in Cryptography (RSA), Primality Testing.	
	NP-Complete Problems	**(07 Hours)**
	Polynomial Time, Verification, NP-completeness and reducibility, Approximation Algorithms: Vertex-cover Problem, the Travelling Salesperson Problem, The Set Covering Problem, The Subset-sum Problem, Local Search Heuristics.	
	Tutorials will be based on the coverage of the above topics separately.	**(30 Hours)**
		(Total Contact periods / Hrs.: 45 Hrs. + 15 Hrs. = 60 Hrs.)

3.	**Tutorials will be based on the topics as follows.**
1	On exploring different techniques for analysing algorithms, including asymptotic and empirical methods and On learning to formulate and solve recurrence relations to determine the time complexity of recursive algorithms.
2	On studying proof techniques such as induction, contradiction, and direct proofs to establish algorithm correctness.
3	On understanding how amortized analysis determines average-case performance over multiple operations, especially in data structures.
4	On diving into probabilistic analysis to evaluate the expected performance of algorithms, focusing on randomized algorithms.
5	On mastering divide and conquer techniques for classic problems like merge sort and quick sort, and analysing sorting algorithms for best, worst, and average cases.
6	On studying non-comparison sorts like counting sort, radix sort, and bucket sort, and learning about order statistics, medians, and the min-max problem.
7	On exploring dynamic programming for optimization problems like matrix multiplication, longest common subsequence, and 0/1 knapsack.

8	On learning backtracking and branch & bound techniques, applying them to problems like N-Queens, and analysing advanced search algorithms like LCBB.
9	On understanding number theory concepts such as GCD, modular arithmetic, and cyclic groups, and their applications in cryptography and primality testing.
10	On introducing NP-complete problems, polynomial-time verification, and strategies like reductions and approximation algorithms for handling NP-completeness

4.	Books Recommended
1	Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C., Introduction to Algorithms, 4th Edition, MIT Press, 2022.
2	Skiena, S., The Algorithm Design Manual, 3rd Edition, Springer, 2020.
3	Sedgewick, R., & Wayne, K., Algorithms, 4th Edition, Addison-Wesley, 2011.
4	Levitin, A., Introduction to the Design and Analysis of Algorithms, 3rd Edition, Pearson, 2011.
5	Bertsekas, D. P., Dynamic Programming and Optimal Control, 4th Edition, Athena Scientific, 2017.
6	Weiss, M. A., Data Structures and Algorithm Analysis in C++, 4th Edition, Pearson, 2013.
7	Gilles Brassard and Paul Bratley, Fundamentals of Algorithmics, PHI Learning, New Delhi, 2010

5.	Other Reference Books
1	Knuth, D. E., The Art of Computer Programming, Generating All Trees--History of Combinatorial Generation, Addison-Wesley, 2006.
2	Shoup, V., A Computational Introduction to Number Theory and Algebra, 2nd Edition, Cambridge University Press, 2009.
3	Berndt, B. C., Number Theory in the Spirit of Ramanujan, American Mathematical Society, 2006.
4	Garey, M. R., & Johnson, D. S., Computers and Intractability: A Guide to the Theory of NP-Completeness, W. H. Freeman, 1979.
5	Vazirani, V. V., Approximation Algorithms, Springer, 2001.