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ENGINEERS WITH
SOCIAL RESPONSIBILITY

NAAC Accredited
Recipient of Centre of Excellence Award by the Government of Gujarat
Recipient of '5 Star' in GSIRF Ranking by Government of Gujarat

B. Tech in Mathematics and Computing

Maths and Computing (MnC) is a fusion of Mathematics and Computer Science that has obtained wide acceptance as a distinct discipline over the past few years. It arises out of dealing with Mathematics as a fundamental tool in computing and with Computing as a primary component of mathematical problem solving. The program has been specially designed to meet the increasing needs of professionals who would be able to respond to the convergence between mathematical and computational problem solving. The program aims at expanding the mathematical, algorithmic and computational thinking of students and at providing sufficient and solid foundation for skill development in MnC. A strong mathematical foundation would enable the study and analysis of abstract concepts and to model many real life problems mathematically, algorithmic thinking would provide ways to solve these mathematical problems in an automated way and computational thinking would allow for evaluating the efficiency of these solutions. The program aims to provide exposure to the students who wish to build a professional career in MnC, working at the cutting edge of technology, research and development. On successful completion of the program, the students would have acquired essential theoretical, technical and practical knowledge for solving real-world problems, and will have the ability to demonstrate excellent analytical, logical and problem solving skills. The students would have also acquired social and ethical attributes that would enable them in applying their skills for societal needs with effective communication – orally, in writing and on multi-media platforms.

Program Outcomes (POs)

As stated by NBA, POs represent the knowledge, skills and attitudes the students should have acquired at the end of a four-year engineering program.

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PO1: **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme Specific Outcomes (PSOs)

PSO1: To model computational problems by applying mathematical concepts and solving real-world problems using algorithmic techniques.

PSO2: To apply the mathematical and statistical approaches for analyzing, designing and development of computing systems in interdisciplinary applications.

Programme Educational Objectives (PEOs)

PEO1: To prepare students with a strong foundation of Mathematics and Computing, who will be able to solve and analyze real-world problems.

PEO2: To prepare students with the necessary theoretical background and practical knowledge to work professionally as scientists, analysts, entrepreneurs, developers, and project personnel.

PEO3: To prepare graduates who will be successful professionals in industry, government, academia, research, entrepreneurial pursuit and consulting firms.

PEO4: To prepare students who will be socially responsible citizen with ethical and leadership qualities and effective interpersonal skills.

Program Structure

The curriculum is organised with core courses, elective courses, internships and project works. The core courses are fundamental to building core competence and foundation for MnC domain knowledge areas. During senior years, students will have adequate **choice of electives** in order to dwell deeper into contemporary areas of their

interest. A unique feature of the program is the mandatory independent project which is expected to give students a feel for their research ability in an area of their choice. The curriculum also includes a mandatory rural internship and a mandatory summer research/industrial internship. Finally, a student is required to take at least a semester long BTech Project (BTP) during which the students demonstrate their ability in using the knowledge and skills acquired during the program. The semester-wise structure of the curriculum is as follows:

YEAR – I				
Semester I	**L-T-P-C**	**Winter Break**	**Semester II**	**L-T-P-C**
Mathematical, Algorithmic, and Computational Thinking	3-1-0-4		Functions of Single Variable and ODEs	3-1-0—4
Computer Organization and Programming Computer Organization and Programming Lab	3-0-0—3 0-0-4—2		Object Oriented Programming	2-0-2—3
Discrete Mathematics	3-1-0—4		Data Structures and Algorithms	3-0-2—4
Digital Logic Design	1-0-2—2		Linear Algebra	3-1-0—4
Language and Literature	3-0-0—3		Approaches to Indian Society	3-0-0—3
Semester credits	**13-1-8—18**		**Semester credits**	**13-2-6—18**
Summer – I				

YEAR – II				
Semester III	**L-T-P-C**	**Winter Break**	**Semester IV**	**L-T-P-C**
Probability and Random Processes	3-1-0—4	R	Mathematical Statistics	3-1-0—4
Operating Systems	3-0-2—4	U	Theory of Computation	3-1-0—4
Design and Analysis of Algorithms	3-1-0—4	R	Parallel and Distributed, Algorithms	3-1-0—4
Functions of Several variables and PDEs	3-1-0—4	A	Real and Complex Analysis	3-1-0—4
Database Management Systems	3-0-2—4	L	Numerical and Computational Methods	3-0-2—4
Science, Technology, Society	3-0-0—3	**Internship**	Environmental Studies	2-0-0—2
Semester credits	**18-4-2—23**	**0-0-8—4**	**Semester credits**	**17-3-4—22**
Summer – II				

YEAR – III				
Semester V	**L-T-P-C**	**Winter Break**	**Semester VI**	**L-T-P-C**
Mathematical Optimization	3-1-0—4		Machine Learning	3-0-2—4
Modelling and Simulation	3-0-2—4		Open Elective – 1	3-0-0—3
Algebraic Structures	3-1-0—4		MnC Elective – 3	3-0-0—3 3-1-0—4 3-0-2—4
Principles of Economics	3-0-0—3		MnC Elective – 4	3-0-2—4 3-1-0—4 3-0-0—3
MnC Elective - 1	3-0-2—4 3-1-0—4 3-0-0—3		MnC Elective – 5	3-0-2—4 3-1-0—4 3-0-0—3
MnC Elective - 2	3-0-2—4 3-1-0—4 3-0-0—3		Independent Project – 1/ MnC Elective – 6	0-0-6—3 3-0-2—4 3-1-0—4 3-0-0—3
Semester credits	**18-x-y—(21-23)**		**Semester credits**	**x-y-z—(19-23)**

Summer - III : Summer Research/Industrial Internship (0-0-12—6)

YEAR – IV				
Semester VII	**L-T-P-C**	**Winter Break**	**Semester VIII**	**L-T-P-C**
MnC Elective – 6 / Independent Project – 1	3-0-2—4 3-1-0—4 3-0-0—3 0-0-6—3		MnC Elective – 10 / BTP-1	3-0-2—4 3-1-0—4 3-0-0—3 0-0-8—4
MnC Elective – 7	3-0-2—4 3-1-0—4 3-0-0—3		BTP-2	0-0-18—9
MnC Elective -8	3-0-2—4 3-1-0—4 3-0-0—3			
Open Elective – 2	3-0-0—3			
MnC Elective – 9	3-0-2—4 3-1-0—4 3-0-0—3			
Independent Project – 2 / MnC Elective – 10 / BTP – 1	0-0-6—3 3-0-2—4 3-1-0—4 3-0-0—3 0-0-8—4			
Semester credits	**x-y-z—(18-23)**		**Semester credits**	**x-y-z—(12-13)**

Representative list of electives

Graph Theory and Algorithms	Data Mining and Visualization	Stochastic Simulation
Approximation Algorithms	Human Computer Interaction	Dynamical Systems
Computational Complexity	Natural Language	Computational Number Theory
Randomized Algorithms		

Quantum Computing Introduction to Cryptography Block Chain and Cryptocurrencies Adversial Machine Learning Machine Learning and Security Introduction to coding theory and Applications Compilers	Processing Network Science Time Series Analysis Software Engineering Hypothesis Testing Multivariate Statistics Bayesian Analysis Financial Data Analysis Machine Learning in Finance	Fluid Dynamics Game Theory Queuing theory Operations Research Functional Analysis Stochastic calculus for finance Computational finance

SEMESTER – I	
Mathematical, Algorithmic, and Computational Thinking (3-1-0-4)	Under preparation; to evolve over time
Computer Organization and Programming (3-0-0-3 and 0-0-4-2)	Model of computer and working principle, digital logic building blocks, information representation and number systems, basic elements of a processor, storage and I/O interface, assembly-level programming, execution of program and programming languages, pipelining, components of CPU and external interface, main memory, instruction execution, instruction format, instruction set, addressing modes, flags and conditional instructions, procedure call and return, instruction cycle and micro-operations, handling different addressing modes, handling control transfer instructions, basics of memory and cache, direct-mapped caches – misses, writes and performance, associative and multi-level caches, virtual memory and address translation, paging and segmentation, page replacement algorithms, page frame allocation and thrashing Idea of algorithms, flowchart, pseudocode, introduction to programming language concepts, variables and memory, types of software and compilers, introduction to C programming language,

	variables and variable types in C, functions, address and content of variables and types, assignment statement and operators in C, arithmetic and relational expressions, logical operators and change in control flow, use of logical operators in branching, if...else statement, switch statement, implementing repetitions (loops), loops through for statement, programming using arrays, linear search, character array and strings, string operations, 2D array operation, scanf and printf functions, function prototype, parameter passing in function, substitution of # include and macro, use of pointers in function, data representation, recursion, structure, structure with typedef, pointer in structures, dynamic allocation and file
Analysis of Functions of Single Variable and ODEs (3-1-0-4)	Real numbers, functions, sequence, limits and continuity, properties of continuous function, uniform continuity, derivative, maxima and minima, Rolle's theorem, mean value theorem, indeterminate forms, Taylor's polynomial and Taylor's series, curve sketching, infinite series, tests of convergence, power series, Riemann integral, Riemann integrable function, applications of Riemann integration, Introduction to ordinary differential equations, existence and uniqueness of solutions of differential equations, first order differential equations, exact differential equations, first order linear differential equations, higher order linear differential equations, solution of higher order homogeneous linear equations, solutions of higher order non-homogeneous linear equations, Cauchy-Euler equations, power series solution of second order homogeneous equations, BVPs for second order differential equations, Transform Calculus – Introduction to integral transforms and Laplace transformation, existence of Laplace transformation, Shifting properties of Laplace transformation, Laplace transformation of derivatives and integrals of a function, Laplace transform of periodic functions, Laplace transform of some special functions like error function, Dirac delta function, Bessel function, inverse Laplace transform, convolution and its application, evaluation of integrals using Laplace transform, Solution of ODEs with constant coefficients using Laplace transform, solution of ODEs with variable coefficients using Laplace transform, introduction to integral equation and its solution process, Fourier series, Fourier series of even and odd functions, Fourier series of functions with arbitrary period, Half-range Fourier series, introduction to Fourier transform
Mathematical and Computational Tools (1-0-2-2)	Under preparation; to evolve over time (Python, Mathematica, Latex)

Language and Literature (3-0-0-3)	Same as in ICT programme
SEMESTER – II	
Probability and Random Processes (3-1-0-4)	Random experiment, sample space, axioms of probability, probability space, conditional probability, independence of events, multiplication rule, total probability rule, Bayes' theorem, random variable, cumulative distribution function, types of random variables, probability mass function, probability density function, distribution of function of random variables, mean and variance, higher order moments and inequalities, generating functions, common discrete distributions, applications of random variables, random vector and joint distribution, joint probability mass function, joint probability density function, independent random variables, functions of several random variables, order statistics, conditional distributions, random sum, moments and covariance, variance-covariance matrix, multivariate normal distribution, probability generating function and moment generating function, correlation coefficient, conditional expectation, modes of convergence, law of large numbers, central limit theorem, stochastic processes, classification of stochastic processes, Bernouli process, Poisson process, simple random walk, time series, strict sense stationary process, wide sense stationary process, discrete time Markov chain, Chapman-Kolmogrov equations and N-step transition matrix, classification of states, limiting and stationary distributions, continuous time Markov chain, state transition diagram and Chapman-Kolmogrov equation, infinitesimal generator and Kolmogrov differential equations, limiting and stationary distributions, birth-death process, Poisson process, non-homogeneous and compound Poisson process, introduction to queueing models and Kendall notation, M/M/1 queueing model, M/M/c queueing model, M/M/1/N model, other Markovian queueing models, transient solution of finite capacity Markovian queues.
Object Oriented Programming (2-0-2-3)	Recap of structured programming - programs with I/O and loops, arrays and strings, sorting and searching, constants and inline functions, reference and pointers, default parameters and function overloading, operator overloading, dynamic memory management,

Data Structures and Algorithms (3-0-2-4)	Abstract data types – data + methods, list data type, access and update methods, doubly linked list data type, arrays, ADT stacks, applications of stacks for checking balanced parenthesis, infix and postfix expression evaluation, ADT queues, merging using queue ADT and queue types, non-linear data structures – Tree ADT and its traversals, Binary Tree ADT and its traversals, applications of Tree ADTs in Huffman coding, Dictionary - BSTs, balanced BSTs, ADT priority queues and heaps, Graph ADT, transitive closure, Floyd Warshall algorithm, connectedness, spanning trees, BFS, DFS
Discrete Mathematics (3-1-0-4)	Sets, set operations and laws of set operations, the principle of inclusion-exclusion and its applications, fundamentals of logic, logical inference, methods of proof of an implication, first order logic, rules of inference for quantified propositions, mathematical induction, graphs, isomorphism and subgraphs, walks, paths and cycles in graphs, bipartite graph, Euler graphs, Hamilton graphs, shortest path problem, planar graphs, relations, properties of relations, graph of a relation, matrix of a relation, closure of relation, Warshall's algorithm, partially ordered relation, posets, lattices, Boolean algebra, Boolean function, discrete numeric function, generating function, recurrence relations and its applications, permutations, combinations and the binomial theorem, congruences and modular arithmetic, the Chinese remainder theorem, the Euclidean algorithm
Approaches to Indian Society (3-0-0-3)	Same as in ICT programme
SEMESTER – III	
Mathematical Statistics (3-1-0-4)	Introduction to descriptive statistics and frequency distributions – types of data, categorical data, describing categorical data, describing numerical data, association between categorical variables, association between numerical variables, , graphics and plots, central tendency of data – arithmetic mean, median, quantiles, mode, geometric and harmonic mean, range, interquartile range, quartile deviation, absolute deviation and absolute mean deviation, mean least squared error, variance and standard deviation, coefficient of variation, raw and central moments, skewness and Kurtosis, correlation coefficient, rank correlation coefficient, method of least squares, correlation and regression, normal distribution, bivariate normal distribution, distribution of order statistics, Chi-square distribution, t-distribution, F-distribution, unbiased and consistent estimators, LSE, MME, MLE, MSE, UMVUE, sufficiency, completeness, Rao-Blackwell theorem and its applications, confidence intervals, types of errors, Neyman-Pearson fundamental lemma and its applications, testing of hypothesis – testing of normal mean, testing of normal variance, large sample

	test for variance, paired t-test, testing equality of proportions, Chi-square test for goodness fit, testing for independency in rxc contingency
Operating Systems (3-0-2-4)	Introduction to OS, PC hardware, from programs to processes, sharing the CPU, virtual memory, MMU mapping, segmentation, memory management in xv6, PC booting, create, execute and exit from processes, system calls for process management, interrupts, interrupt handling, software interrupts and system calls, CPU context switching, CPU scheduling, priority based scheduling algorithm, multi-processor scheduling, scheduling in Linux, completely fair scheduling, inter process communication, synchronization, software solutions for critical sections, Bakery algorithm, hardware locks, mutexes, semaphores, dining philosophers problem, deadlocks, dealing with deadlock, threads, OS security, information flow policies, buffer overflows, preventing buffer overflow attack
Design and Analysis of Algorithms (3-1-0-4)	Input size, worst case, average case, quantifying efficiency – O( ), Omega(), Theta( ), analysis of iterative and recursive algorithms, substitution method, The master method, divide-and-conquer, Straseen's algorithm, arrays and lists, searching in an array, selection sort, insertion sort, merge sort and its analysis, quick sort and its analysis, randomized quicksort, heap, heapsort, decision tree, linear time sorting, radix sort and bubble sort, order statistics, randomized order statistics, worst case linear time order statistics, hash function, open addressing, universal hashing, perfect hashing, BST sort, randomly build BST, Red Black tree, augmentation of data structure, interval trees, fixed universe successor, Van Emde Boas data structure, amortized analysis, representing graphs, DFS and BFS with applications, topological sort on DAGs, longest paths on DAGs, single source shortest paths – Dijkstra's algorithm and its analysis, negative edge weights – Bellman Ford algorithm, all pair shortest paths, minimum cost spanning tree – Prim's and Kruskal's algorithm, union-find using arrays, union-find using pointers, priority queues, heaps – updating values and sorting, counting inversions, closest pair of points, BSTs – interval scheduling, scheduling with deadlines, Huffman codes, dynamic programming – memorization, grid paths, common subwords and subsequences, edit distance, matrix multiplication, matrix inversion and decomposition, Knuth-Morris-Pratt algorithm, Rabin-Karp algorithm, integer polynomial operations, Chinese remainder, DFT, LP modelling – production planning and bandwidth allocation, network flows – Edmond's matching algorithm, Ford-Fulkerson method, Edmond-Karp algorithm, reductions, checking algorithms, P and NP, approximation algorithms
Algebraic Structures	Set theory, binary relation, equivalence relation, mapping, permutation, binary composition, groupoid, group, basic properties

(3-1-0-4)	of groups and group tables, order of an element, subgroup, types of groups, cyclic group, subgroup operations, group homomorphisms, group isomorphisms, normal subgroups, equivalence relations, cosets and Lagrange's theorem, quotient groups, first, second and their isomorphism theorems, Cauchy's theorem, symmetric groups, odd and even permutations, alternating groups, group actions, orbits and stabilizers, counting formula, Cayley's theorem, class equation, group action on subsets, rings, polynomial rings, homomorphisms, kernels, ideals, quotient rings, first isomorphism and correspondence theorems, prime ideals, maximal ideals, integral domains, existence of maximal ideals, field of fractions, Noetherian rings, Hilbert basis theorem, irreducible and prime elements, GCD, principal ideal domains, unique factorization domains, Gauss lemma, Eisenstein criterion, field extensions, degree of a field extension, algebraic elements of a field, field homomorphisms, splitting fields, finite fields
Theory of Computation (3-1-0-4)	Alphabets, strings, languages, finite representation, CFG, derivation trees, regular grammars, finite automata, nondeterministic finite automata, equivalence of NFA and DFA, language of DFA, Myhill-Nerode theorem, building DFA, minimization of finite automata, subset construction, RE, FA, RG and their equivalences, variants of finite automata, properties of regular languages, homomorphism, substitution, pumping lemma, Ardena's theorem, two way FA, finite automata with output, equivalence of Moore and Mealy machines, simplification of CFG, normal forms of CFG, properties of CFLs, derivation/parse tree, left and rightmost derivations, ambiguity of CFG, simplification of CFG, algorithms to construct reduced grammar, elimination of null and unit productions, Chomsky normal form, Greibach normal form, pushdown automata, equivalence of PDA and CFG, Turing machines, Turing compatible functions, combining Turing machines, multi-input, Turing decidable language, variants of Turing machines, structured grammars, decidability and undecidability, time bounded Turing machines, P and NP, NP-Completeness, NP-Complete problems, Rice's theorem, Chomsky hierarchy, new paradigms for computing – DNA computing, membrane computing, quantum computing
Science, Technology, Society (3-0-0-3)	Same as in ICT programme
SEMESTER – IV	
Analysis of Functions of Several Variables and PDEs	Limit of functions of two variables, evaluation of limit of functions of two variables, continuity of functions of two variables, partial derivatives of functions of two variables, partial derivatives of higher order, derivative and differentiability, differentiability of functions of two variables, composite and homogeneous functions, chain rule,

(3-1-0-4)	Euler's theorem for homogeneous functions, Taylor's theorem for functions of two variables, extrema of functions of two variables, constrained extrema-Lagrange multipliers, improper integrals, Beta & Gamma function, differentiation under integral sign, double integrals, double integral over a region, double integrals in polar form, change of order of integration, change of variables in a double integral, surface area through double integrals, triple integrals, area of a plane region, surface integral, volume integral, Gauss divergence theorem Vector calculus – vector differentiation, successive differentiation, integration of vector function, gradient of a function, divergence and curl, directional derivatives, level surfaces, line integral, surface integral, Green's theorem, volume integral, Gauss theorem, Gauss divergence theorem, Stoke's theorem Origins and classification of first order PDE, principle of linear superposition, standard Eigenvalue problem and special ODEs, adjoint operator, generalized Sturm-Louiville problem, properties of adjoint operator, separation of variables – rectangular coordinate system, solution of elliptical PDE, solution of hyperbolic PDE, existence and uniqueness of solutions, Cauchy method of characteristics, Charpit's method, second order PDE with variable coefficients, classification and canonical form of second order PDE, Laplace equation, Laplace and Poisson equation, one-dimensional wave equation and its solution, two dimensional wave equation and its solution
Data Storage and Management (3-0-2-4)	Storage, processing, networking, naming and storing, storage filesystems, storage media, storage access mechanisms, storage protocols – access architecture, hard disks, SCSI, communication protocols for networked storage systems, types of storage devices and systems, long-term storage, storage interfaces and device drivers, storage filesystem design, storage reliability, performance and security, theoretical foundations – consistency and commit problems, Paxos, group communication problem, message ordering, ordering in file systems, highly scalable distributed file systems, BigTable DBMS - ER model, relational model, relational algebra –basic operators, composition of operators, additional operators, extended relational operators, database modifications, TRC, SQL – basic and advanced queries, updates, joins, views and triggers, normalization theory, - 1NF, 2NF, 3NF, BCNF, MVD, physical design, indexes – hashing, tree-based indexing, query processing – nested loop joins and merge join, hash join and other operations, query optimization – equivalent expressions and simple equivalence rules, complex

	equivalence rules, join order, heuristics and sizes, transaction processing – properties and failures, states and systems, recovery systems – deferred database modification, immediate database modification, checkpointing and shadow paging, schedules – conflict serializability, view serializability, result equivalence and testing for serializability, recoverability, concurrency control – locks, two-phase locking protocol, timestamp ordering protocol, validation-based protocol, multiple granularity for locks, deadlock prevention and deadlock detection, deadlock recovery and update operations, NoSQL – columnar families, different NoSQL systems, Big data
Parallel and Distributed Algorithms (3-1-0-4)	Parallel algorithm models - Shared memory models and interconnection networks, performance of parallel algorithms, cost and optimality, dense algorithms – matrix multiplication, matrix multiplication using mesh networks and hypercube networks, block matrix multiplication, decomposition and mapping techniques – parallel query processing, dense LU factorization, comparator networks and sorting – OEMS, BSMS, analysis and applications of parallel algorithmic techniques, optimal list colouring, optimal list ranking, expression tree evaluation, merging, Cole's merge sort, sorting lower bound, parallel searching and selection, components of a graph, components on CREW model, vertex colouring, sorting on 2D, 3D meshes, offline routing on a 2D mesh, algorithm on interconnection networks – mesh of trees, hypercube, CCC, butterfly network, Benes network, shuffle-exchange network, deBruijn network, parallel complexity theory – P-complete and NC reductions TBD
Linear Algebra (3-1-0-4)	System of linear equations, Gauss elimination for solving system of linear equations, RREF, rank of a matrix, vector space, linear independence of vectors, spanning set of a vector space, basis and dimension, rank of a matrix, linear transformations, row space, column space, rank-nullity theorem, determinants and their properties, orthonormal basis and geometry in R^2, isometries, linear functionals, the dual space, dual basis, subspace annihilators, the double dual, Eigenvalues and Eigenvectors, Cayley-Hamilton theorem and minimal polynomial, diagonalization of real symmetric matrices, diagonalization and its applications, invariant subspaces, triangulability, independent subspaces and projection operators, direct sum decomposition and project operators, the Primary decomposition theorem abstract vector spaces, inner product spaces, Gram Schmidt process, positive definite and quadratic forms, generalized Eigenvectors and Jordan canonical form, SVD, spectral decomposition, types of matrices
Numerical and	Sign integer representation, computer representation of numbers,

Computational Methods (3-0-2-4)	floating point representation, round-off error, error propagation in computer arithmetic, addition and multiplication of floating point numbers, conditioning and condition numbers, stability of numerical algorithms, error analysis, Linear systems, Gaussian elimination with partial pivoting, LU decomposition, Jacobi and Gauss Seidel methods, iterative methods, introduction to non-linear equations and bisection method, regula falsi and secant methods, Newton-Raphson method, fixed point iteration method, system of non-linear equations, Jacobi's method for computing Eigenvalues, power method, inverse power method, polynomial interpolation, Newton's forward/backward difference and derivation of general error, error in approximating a function by a polynomial using Newton's forward/backward difference formula, central difference formula, Lagrange interpolation formula, divided difference interpolation, Hermite's interpolation, numerical differentiation by interpolation formula, numerical differentiation based on Lagrange's interpolation and divided difference formula, maxima and minima of a tabulated function and differentiation errors, differentiation based on finite difference operators, method of undetermined coefficients and derivatives with unequal intervals, methodology of numerical integration and rectangular rule, quadrature formula and trapezoidal rule with associated errors, Simpson's 1/3 rule with associated errors, composite Simpson's 1/3rd rule and 3/8th rule, Gauss Legendre with 2-point and 3-point formula, numerical solutions of ODE – R-K methods and multi-step method, numerical solutions of PDE Monte Carlo method, genetic algorithms and heuristics, metropolis, filtering algorithms – Fourier transforms, convergence and error analysis of each technique
Environmental Studies (2-0-0-2)	Same as in ICT programme
SEMESTER – V	
Mathematical Optimization (3-1-0-4)	Assumptions and mathematical modelling of LPP, geometry of LPP, graphical solution of LPP, Simplex method, Big-M method, two phase method, special cases of LPP, degeneracy of LPP, sensitivity analysis, duality theory, dual simplex method, post optimality analysis, ILP, branch and bound method, transportation problem and its solutions, assignment problems, project management, critical path analysis, PERT, shortest path algorithm, travelling salesman problem, mixed integer programming problem, single variable optimization, NLP, graphical solution of NLP, types of NLP, one dimensional constrained optimization, unconstrained

	optimization, region elimination technique, multivariate unconstrained optimization, NLP with equality constrained, constrained NLP, constrained optimization, KKT, feasible direction, penalty and barrier method, convex sets and functions, properties of convex functions, convex programming problems, KKT optimality conditions, quadratic programming problems, separable programming, geometric programming, dynamic programming, search techniques, multi-objective decision making, multi-attribute decision making
Modelling and Simulation (3-0-2-4)	Introduction to modeling process, Modeling Concepts, Model Classifications, System Dynamics Models, Compartment model, Discrete and Continuous time deterministic models, logistic equation, models of opinion and epidemic spread, competition models. Stochastic Models, Discrete and Continuous distributions, Markov Chains, Limit theorem for Markov Chains in discrete and continuous time, Poisson processes, Brownian Motion, Random Walk, Queueing Systems, Monte Carlo Simulations. Birth death processes, stochastic opinion and epidemic spread models. Introduction to Cellular Automata Simulations, Binary and probabilistic cellular automata, Ising spin system and applications.
Machine Learning (3-0-2-4)	The learning paradigm, foundation of AI and ML, intelligent autonomous systems and AI, applications of ML, characterization of learning problems, hypothesis space and inductive bias, evaluation and cross-validation, objects, categories and features, feature related issues, scenarios for concept learning, forms of representation, decision trees, Bayesian belief networks, ANNs, genetic algorithm, logic programming, inductive learning based on symbolic representations and weak theories, generalization as search, decision tree learning algorithms, instance based learning, cluster analysis, ML enabled by prior theories, explanation based learning, inductive logic programming, reinforcement learning, linear regression, least squares, gradient descent, generalized function for linear regression, goodness of fit, bias-variance trade off, gradient descent algorithms, Deep learning – logistic regression, binary entropy cost function, OR gate via classification, NOR, AND, NAND, XOR gates, differentiating the sigmoid, gradient of logistic regression, multinomial classification, multinomial logistic regression, biological neuron, structure of an artificial neuron, feedforward neural network, back propagation, CNN, types of convolution, CNN architecture, train network for image classification, semantic segmentation, hyperparameter optimization, transfer learning, activation functions, learning rate decay, weight initialization, data normalization, batch norm, RNNs, Hebbian learning and associative memory, Hopfield networks and Boltzman machines, sequence classification, training RNNs – loss and BPTT, vanishing gradients and TBPTT, RNN architectures, LSTM, Deep

	RNNs and Bi-RNNs, Knn, feature selection, feature extraction, collaborative filtering, binary decision trees, binary regression trees, bagging, random forest, boosting, gradient boosting, unsupervised learning and Kmeans, agglomerative clustering, Naïve Bayes, MLE, PCA, SVM, MLE, MAP, Bayesian regression, generative model, GAN, VAE, applications, ML visualization.
Principles of Economics	Same as in ICT programme
SEMESTER – VI	
Real and Complex Analysis (3-1-0-4)	Countable and uncountable sets, concepts of metric space, open ball, closed ball, limit point of a set, ordered set, lub, glb, compact set, Heine Borel theorem, Weierstrass theorem, Cantor set and its properties, derived set and dense set, limit of a sequence and monotone sequence, properties of limit of sequences, ratio test, Cauchy's theorems on limits of sequences of real numbers, fundamental theorem of limits, Bolzano-Weierstrass theorem, criteria for convergent sequence, criteria for divergent sequence, Cauchy sequence, Cauchy convergence criteria for sequences, infinite series of real numbers, convergence criteria for series of positive real numbers, comparison test of series, absolutely and conditionally convergent series, rearrangement theorem and test for convergence of series, ratio and integral test for convergence of series, Raabe's test for convergence of series, limit of functions and cluster point, divergence criteria for limit, left and right hand limits for functions, limit of functions at infinity, continuous functions (Cauchy's definition), continuous functions (Heine's definition), properties of continuous functions, boundedness theorem and min-max theorem, location of root and Bolzano's theorem, uniform continuity and related theorems, absolute continuity and related theorems, types of discontinuities, relation between continuity and compact sets, differentiability of real valued functions, local min-max Cauchy's and Lagrange's mean value theorem, Rolle's mean value theorem and its applications. Analytic function, Cauchy-Riemann equations, harmonic function, harmonic conjugate and Milne's method, complex integration, Cauchy's theorem, Cauchy's integral formula for the derivatives of analytic function, Morera's theorem, Liouville's theorem, Fundamental theorem of Algebra, Winding number and maximum modulus principle, sequences and series, uniform convergence of series, power series, Taylor's series, Laurent series, zeros and singularities of analytic function, residue of a singularity, residue theorem, meromorphic functions, evaluation of real integrals using residues, bilinear transformations, conformal mapping

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