Indian Institute of Engineering Science and Technology, Shibpur

Department of Computer Science and Technology

B. Tech. (CST) Syllabus

1st and 2nd Semester

Introduction to Computing (1st Sem.: CS1101, 2nd Sem.: CS1201)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Number system and Codes:** Positional & non positional number systems, Binary, Octal, Hexadecimal number system and Conversion, Representation of negative numbers & real numbers, Fixed and floating point numbers. Characteristics codes (ASCII, EBCDIC etc.) and others like Grey, Excess-3 etc.	6
2	**Arithmetic and Logic:** Logic operations & gates, Half adder. & full adder subtraction using add. Repetitive addition and subtraction to accomplish multiplication & division etc.	5
3	**Computer Organisation:** CPU, Memory and I/O devices – Commonly used peripherals. Role of the CPU, Memory and I/O devices in the context of solving a problem.	6
4	**Problem Solving Steps and Program Development Cycle :** Systemetic decomposition, Flowchart, Algorithm, the three constructs (sequential, conditional and iterative). Edit, compilation, Debugging & execution.	3
5	**Introduction to Programming In C:** Idea of High level, Assembly level & M/c level language. Interpretation and compilation. Variables and data types (basic), simple programs, assignment, decision, loops, scope: Global & local, control structure (if, if-else, switch, for, while, do while, break and continue) Structural data type (Array, record, file, set etc.), Function, Recursion, Pointers, Introduction to dynamic data structure.	18

Computer Lab. (1st Sem.: CS1171, 2nd Sem.: CS1271)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Introduction to Linux commands, vi editor and program writing and executing	6
2	Assignments on conditional statements (if, else)	3
3	Assignments on control structure (for, while, do-while) - I	3
4	Assignments on control structure (switch, break and continue) - II	3
5	Assignments on structural data type (Array, record)	6
6	Assignments on function and recursive function	3
7	Assignments on dynamic data structure	3
8	Assignments on file handling and file operations	3

3rd Semester

Core Theory – I: Discrete Structures (CS2101)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Logic:** Propositional Logic: Syntax, Semantics, Validity and Satisfiability, Basic Connectives and Truth Tables, Logical Equivalence: The Laws of Logic, Logical Implication, Rules of Inference, Use of Quantifiers.	8
2	**Proof Methods:** Proof Methods and Strategies, Forward Proof, Proof by Contradiction, Proof by Contraposition, Proof of Necessity and Sufficiency, The Well-Ordering Principle, Proof by Induction, Strong Induction.	8
3	**Sets, Relations, and Functions:** Operations and Laws of Sets, Cartesian Products, Binary Relation, Closures of Relations, Partial Ordering Relation, Equivalence Relation, Image of a Set, Sum and Product of Functions, Bijective Functions, Inverse and Composite Function, Size of a Set, Finite and Infinite Sets, Countable and Uncountable Sets, Cantor's Diagonal Argument, Power Set theorem, Schroeder-Bernstein Theorem.	10
4	**Generating Function and Recurrence Relations:** Numeric Functions and their Asymptotic Behavior, Generating Functions, Use of Generating Function to Solve Combinatorial Problems, Recurrence Relations and their Application in Analyzing Algorithms.	4
5	**Graphs and Trees:** Graphs and their properties, Degree, Connectivity, Path, Cycle, Graph Representation, Sub Graph, Isomorphism, Eulerian and Hamiltonian Walks, Graph Coloring, Shortest Path Problems; Trees: Introduction to Trees, Application of Trees, Tree Traversals, Spanning Tree, Minimum Spanning Trees.	10

Reference Books:

1. Kenneth Rosen, Discrete Mathematics and Its Applications, 7th Edition, McGraw Hill Publishing Co.
2. Susanna S. Epp., Discrete Mathematics with Applications, 4th edition, Wadsworth Publishing Co. Inc.
3. C. L. Liu and D. P. Mohapatra, Elements of Discrete Mathematics: A Computer Oriented Approach, 3rd Edition, Tata McGraw-Hill.

Core Theory – II: Digital Logic (CS2102)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Number Systems and Binary representations:** 1's complement and 2's Complement representations of numbers, Binary subtraction using 1's complementary Method, Binary subtraction using 2's complementary Method: gray codes, excess-3, BCD, etc	3
2	**Boolean Algebra and Logic gates:** Basic theorems and properties of Boolean algebra, Boolean functions, Canonical and Standard forms, Other logic operations.	3
3	**Simplification of Boolean Functions:** Map Method, Product of sum simplification, NAND and NOR Implementation, Don't- care Conditions, Tabulation method	3
4	**Combinational Logic:** Introduction, Design procedure, Adders, Subtractors,	4

	Code conversion, Analysis procedure, Multilevel NAND and NOR circuits, Exclusive-OR and Equivalence Functions.	
5	**Combinational Logic with MSI and LSI:** Binary Parallel adder, Decimal adder, Magnitude comparator, Decoders and Multiplexers.	5
6	**Sequential Logic:** Flip-flops, Triggering of flip-flops, Analysis of Clocked sequential circuits, State reduction and assignment, Flip-flop excitation tables, Design procedure, Design with state equations, Registers, Shift-registers, Ripple counters Synchronous counters.	11
7	**Digital Integrated Circuits:** Diode as switch. Use of diodes in AND, OR circuits, Transistor as a switch. RTL, DTL, TTL logic gate circuits. MOS as a switch. Basic MOS inverter. MOS and CMOS logic gates. Fan-in and Fan-out of logic gates, propagation delay, Tristate logic.	7

Core Theory – III: Data Structures (CS2103)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Abstract Data Type (ADT) and Algorithm:** ADT - concepts of data types, data structure and ADT, properties applicable for ADT. Algorithm – Properties, Concepts of Time and Space complexity	3
2	**Linked Lists:** Linear Linked List, Circular Linked List, Doubly Linked List, Multi-List, Applications	5
3	**Stacks and Queues:** Concepts and Applications	5
4	**Recursion:** Difference between Recursion and Iteration, Design of Recursive Algorithms	2
5	**Trees:** Binary Trees. Properties, Binary Tree Traversals, Expression Trees, Conversion from General Tree to Binary Tree. Binary Search Trees and Operations on BST, Balanced Tree – AVL trees, 2-3 trees, 2-4 trees, Red-Black trees, B-Trees. Disjoint set union and union find algorithm.	10
6	**Heap:** Heap data structure and priority Queues	3
7	**Graph:** Representations of Graph, Graph Traverssal and its Applications	3
8	**Sorting:** Insertion Sorts, Exchange Sorts, Selection Sort, Merge Sort, Distribution Sort. Comparisons of Different Sorting Algorithms.	4
9	**Searching:** Sequential Search, Sequential Search in Ordered List, Binary Search, Interpolation Search and their Comparisons	4

Core Theory – IV: Signals and Systems (CS2104)

Module / Sl. No.	Module Name and Topics	No. of Hours
	Course Outcomes: At the end of this course, students will demonstrate the ability to • Understand the concepts of continuous time and discrete time systems; • Represent signals mathematically in continuous and discrete-time, and in the frequency domain. • Analyse, model and simulate discrete-time systems using z-transform. • Design digital filters for various applications. • Apply digital signal processing for the analysis of real-life signals.	

1	**Introduction to Signals and Systems:** Signals and systems as seen in everyday life, and in various branches of engineering and science. Signal properties: periodicity, absolute integrability, determinism and stochastic character. Some special signals of importance: the unit step, the unit impulse, the sinusoid, the complex exponential, some special time-limited signals; continuous and discrete time signals, continuous and discrete amplitude signals. System properties: linearity: additivity and homogeneity, shift-invariance, causality, stability, realizability. Examples.	4
2	**Continuous and discrete-time LTI systems:** Impulse response and step response, convolution, input-output behavior with aperiodic convergent inputs, cascade interconnections. Characterization of causality and stability of LTI systems. System representation through differential equations and difference equations. State-space Representation of systems. State-Space Analysis, Multi-input, multi-output representation. State Transition Matrix and its Role. Periodic inputs to an LTI system, the notion of a frequency response and its relation to the impulse response.	4
3	**Frequency domain and time domain:** Fourier series representation of periodic signals, Waveform Symmetries, Calculation of Fourier Coefficients. Fourier Transform, convolution / multiplication and their effect in the frequency domain, magnitude and phase response, Fourier domain duality. The Discrete-Time Fourier Transform (DTFT) and the Discrete Fourier Transform (DFT). Parseval's Theorem. Concepts of time-frequency distribution, Short time Fourier transform and Wavelet transform, Review of the Laplace Transform for continuous time signals and systems, system functions, poles and zeros of system functions and signals, Laplace domain analysis, solution to differential equations and system behavior.	8
4	**Discrete-time signals and systems:** The Sampling Theorem and its implications. Spectra of sampled signals. Reconstruction: ideal interpolator, zero-order hold, first-order hold. Aliasing and its effects. Relation between continuous and discrete time systems. Sequences; representation of signals on orthogonal basis; Representation of discrete systems using difference equations, Sampling and reconstruction of signals - aliasing; Sampling theorem and Nyquist rate. Z-transform, Region of Convergence, Analysis of Linear Shift Invariant systems using z-transform, Properties of z-transform for causal signals, Interpretation of stability in z-domain, Inverse z-transforms.	4
6	**Applications of signal and system theory:** amplitude and frequency modulation for communication, digital filtering, digital signal processing, simulation and modeling of feedback control systems. Design of Finite and Infinite impulse response digital filters. Low-pass, Band-pass, Band-stop and High-pass filters. Effect of finite register length in FIR filter design.	8
7	Digital Signal Processing tecnhniques: Correlation Functions and Power Spectra, Stationary Processes, Optimal filtering using ARMA Model, Linear Mean-Square Estimation, Wiener Filter, Kalman filter. Least mean square techniques. Adaptive digital filtering.	8

Core Lab/Pract – I: Digital Logic Laboratory (CS2171)

Module / Sl. No.	Module Name and Topics	No. of Hours
1	Logic family: Implementation of OR and AND gates using diodes, Study on characteristics of DTL and TTL inverters using discrete components, Study on characteristics of TTL and CMOS gates.	12

2	Combinational logic circuits: Design and implementation of combinationalcircuits such as, Adders, comparators, parity generator and checker.Implementation of Boolean functions using multiplexer and decoder/de-multiplexer.	12
3	Sequential circuits: Study of latch and flip-flop, design of counters.	12

Core Lab/Pract – II: Data Structures Laboratory (CS2172)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Review of Computing Practice: Assignments using recurssive and non-recurssive functions on Array, etc.	3
2	Assignments based on Stack and its Applications: Parenthesis matching, Conversion of Expressions into Postfix notation and Evaluation , etc.	3
4	Assignments on linked lists (linear, circular, doubly linked list, etc): Implementation and applications.	3
3	Assignments on queues (circular queue, priority queue): Implementation and applications.	3
5	Assignments on tree (binary tree, binary search tree, arithmetic expression tree, balanced trees): Implementation, creation, operations, applications, etc.	6
6	Assignments on search algorithms (sequential, binary and interpolation) on ordered and/or unordered data.	3
7	Assignments on sorting algorithms (recurssive and nonrecurssive algorithms): bubble sort, insertion sort, selection sort, merge sort, quick sort, etc.	6
8	Assignments on graph: Representations, Implementations and Applications such as minimumspanning trees	3

Core Lab/Pract – III: Signals and Systems Laboratory (CS2173)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Realization of linear time invariant systems using opamps	6
2	Study of response of LTI systems to different types of signals	6
3	Implementation of Fourier transform algorithms to study frequency domain	9
4	Simulation studies of modelled LTI systems in time and frequency domain	6
5	Realization of various digital filters suitable for communication systems	9
	Total	36

4th Semester

Core Theory – V: Design and Analysis of Algorithm (CS2201)

Module / Sl. No.	Module Name and Topics	No. of Lectures

1	**Mathematical Foundations and Basic of Complexities:** Time and Space complexity, Asymptotic growth of functions, Recurrences and methods of solving recurrences (substitution, iteration, recursion tree, Master method). Worst, Average and Amortized complexities.	4
2	**Design and Analysis techniques:** Divide and Conquer, Dynamic programming, Greedy Algorithms	4
3	**Sorting and Order Statistics:** Quicksort and Mergesort Complexity analysis as divide and conquer strategy, Lower bound for comparison based sorting, Sorting in linear time (Counting, Radix and Bucket sort), Selection of Medians and ranked elements and their complexity	4
4	**Example Algorithms for dynamic programming (selective list, not exhaustive):** Matrix chain multiplication, Longest common subsequence, Polygon triangulation.	4
5	**Example Algorithms for greedy strategy (selective list, not exhaustive):** Data compression, Matroid based formulation, Scheduling algorithm	4
6	**Advanced Data Structures and applications:** Data structures for dynamic sets, Hashing and associated search complexity, Data structures for disjoint sets, Complexity of union and find operations.	4
7	**Graph algorithms (selective list, not exhaustive):** Minimum Spanning Trees of graph , Connected components of graph, Single source and all-pair shortest paths	4
8	**Number theoretic algorithm:** Fast exponentiation, GCD algorithm, Primality testing algorithm, Handling large size integers, Algorithms for public key cryptography	4
9	**Concept of NP-Completeness:** Polynomial-time verification, Concept of NP-hard and NP-completeness, Notion of approximation Algorithms for NP-complete problems	4
	Total	36

Core Theory – VI: Computer Architecture and Organization – I (CS2202)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** History of computing, von Neumann machine, Instruction and data, fixed- point and floating-point numbers, errors, IEEE standards.	3
2	**Processor design:** Instruction Set Architecture - Instruction format, opcode optimization; operand addressing; Instruction implementation - data movement, branch control, logical, Input/output and debugging instructions; arithmetic instruction implementation – addition and subtraction, multiplication-division, 2's complement multiplication; Booth's algorithm – theory and examples; bit-pair algorithm; high performance arithmetic.	7
3	**Control unit design:** Hardwired control, micro-programmed control design – micro-instruction formats, control optimization.	6
4	**Memory subsystem:** Memory technology, memory interfacing, Memory hierarchy – introduction to virtual memory system; cache memory – performance, address mapping, content addressable memory (CAM)	8
5	**Peripherals:** Basic properties, bus architectures, interfacing of I/O devices, data transfer schemes – programmed I/O, DMA, mass storage, RAID	6
8	**Pipelining:** Pipelining datapath and instructions, speed up, CPI, latency;	6

	linear/non-linear pipeline – reservation table, MAL; super-pipelined and super- scalar processors	

Core Theory – VII: Programming Paradigms (CS2203)

Module / Sl. No.	Module Name and Topics	No. of Hours
1	Programming Languages and Programming Paradigms: Concepts of functional, imperative, Object oriented and logic programming	3
2	Imperative Programming: Cost of introducing assignment, idea of local state (variables), data driven programming.	2
3	Functional Programming: Introduction to computation models Lambda Calculus, LISP as a functional programming language, abstraction with procedures and data, multiple representations of same data, higher order procedures.	6
4	Object Oriented Programming: Review of OOP. Importance of OOP over procedural languages and software crisis. Classes and methods – encapsulation, message passing, base and derived classes, virtual base class, constructor, multiple inheritance. Operator and function overloading. Runtime Polymorphism. Design Patterns. C++ / Java for object oriented programming	20
5	Unified Modeling Language (UML): Introduction to UML for designing object oriented programs	4
6	Introduction to Scripting programming using Python/PHP	3

Core Theory – VIII: Theory of Computation (CS2204)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** Computations, Different models of computation, Language recognizer and generator	2
2	**Regular Languages:** Finite Automata – Deterministic and non determininstic,Regular expression, regular grammar, Equivalence of regular languages, Pumping lemma, Myhill-Nerode Theorem, Minimization of FSM, Properties of the class of Regular languages, Decision algorithm for regular sets.	12
3	**Context Free Language:** Context free grammers (CFG) and languages (CFL), Parse trees, Ambiguous, unambiguous and inherently ambiguous grammars, Normal Forms (Chomsky and Greibach), simplification of CFG, Pushdown automata (deterministic and non determininstic), Acceptance of language by empty stack, final state and their equivalence, Properties of the class of CFLs, Proving a language to be CFL or not, Pumping lemma for CFG, Decision algorithm for CFG	12
4	**Recursive and Recursively enumerable Language:** Unrestricted grammar, Computable function, Turing Machines (deterministic and non determininstic), Equivalence of deterministic and non deterministic TM, Extensions og TM and their simulations, Universal TM, Halting problem of TM, Decidability, Non-computability, Complexity classes, notion of reductions	10

Core Theory – IX: Introduction to Data Science (CS2205)

Course Description:

The course is about learning from data, in order to gain useful predictions and insights. Data Science is the study of extraction of knowledge from data. Data scientist requires an integrated knowledge of mathematics, statistics, data mining and other branches of computer science. The motivation of this course is to introduce students to this rapidly growing field and familiar them with some of its basic techniques and tools. Students will learn concepts, techniques and tools required to deal with various components of data science, including data collection and integration, data preprocessing and exploring, predictive modeling, descriptive modeling, model evaluation, and effective communication. The focus of this course will be placed on integration and synthesis of concepts and their application to solving problems. To make the learning contextual, real datasets from a variety of disciplines including bioinformatics and social network will be used.

Module / Sl. No.	Module Name and Topics	No. of Hours
1	**Introduction:** What is Data Science?- Big Data and Data Science hype, Data types, data quality, data preprocessing, - challenges and applications for text, audio, video, and social media data.	3
2	**Exploratory Data Analysis and the Data Science Process:** Statistical Inference, probability distributions for statistical modeling. Fit a model to data,Linear and non-linear regression, significance of exploratory data analysis (EDA) in data science. **Case study:** Use statistical tool R / Python (like plots, graphs, summary statistics) to carry out EDA, Use APIs and other tools to scrap the Web and collect data.	6
3	**Feature Generation and Feature Selection:** Feature Generation- features generated from different kinds of data like text, image, audio and video data; Feature engineering for deep learning; Feature Selection algorithms – Filters; Wrappers; Decision Trees; Random Forests, etc.;	5
4	**Recommendation Systems:** Building a User facing Data Product - Algorithmic ingredients of a Recommendation Engine - Dimensionality Reduction - Singular Value Decomposition - Principal Component Analysis- **Exercise:** Build your own recommendation system	4
5	**Classification and Cluster Analysis:** Different types of classifiers construction and performance measurements, Ensemble Classifier, Different types of clustering algorithms and cluster evaluation methods. Classification and clustering in incremental datasets	6
6	**Mining Social Network Graphs**: Social networks as graphs, inter connectivity, PageRank, Partitioning of graphs, Neighborhood properties in graphs,Direct discovery of disjoint and overlapping communities in graphs Case study:Take a social network and find all associated communities	4
7	**Mining Text Data:** Tokenziation, part-of-speech tagging, chunking, syntax parsing and named entity recognition; Topic modeling - Probabilistic Latent Semantic Indexing (pLSI) and Latent Dirichlet Allocation (LDA); Latent Semantic Analysis (LSA), document clustering, classification, summarisation and performance evaluation **Case study-1:** Take a set of documents and categorize them using clustering and classification techniques. **Case study-2:** Take a document and make a summary of it.	4
8	**Data Visualization:** Basic principles, ideas and tools for data visualization	2
9	**Data Science and Ethical Issues:** Discussions on privacy, security, ethics - A look back at Data Science - Next-generation data scientists	2

Books:

1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk From The Frontline.

O'Reilly. 2014.
2. Jure Leskovek, AnandRajaraman and Jeffrey Ullman. Mining of Massive Datasets. v2.1, Cambridge University Press. 2014. (free online)
3. Kevin P. Murphy. Machine Learning: A Probabilistic Perspective. ISBN 0262018020. 2013.
4. Foster Provost and Tom Fawcett. Data Science for Business: What You Need to Know about Data Mining and Data-analytic Thinking. ISBN 1449361323. 2013.
5. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Elements of Statistical Learning, Second Edition. ISBN 0387952845. 2009. (free online)
6. Avrim Blum, John Hopcroft and RavindranKannan. Foundations of Data Science.
7. Mohammed J. Zaki and Wagner Miera Jr. Data Mining and Analysis: Fundamental Concepts and Algorithms. Cambridge University Press. 2014.
8. Jiawei Han, MichelineKamber and Jian Pei. Data Mining: Concepts and Techniques, Third Edition. ISBN 0123814790. 2011.
9. Pang-Ning Tan, Michael Steinbach and Vipin Kumar. Introduction to Data Mining

Core Lab/Pract – IV: Algorithm Laboratory (CS2271)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Experimentation of Various comparison sort algorithms (Bubble sort, insertion sort, selection sort, merge sort, randomized quick sort) and comparing their efficiencies	6
2	Experimentation of Linear time sorting algorithms (Bucket sort)	3
3	Experimentation of k-th smallest element of an array	6
4	Applications of Dynamic Programming	3
5	Applications of Greedy algorithms	6
6	Implementation of graph algorithms (minimum spanning tree)	6
7	Implementation of graph algorithms (connected components)	3
	Total	36

Core Lab/Pract – V: Computer Architecture and Organization Laboratory (CS2272)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Design of adders	6
2	Memory module design	9
3	Implementation of simple memory test logic (such as March test)	6
4	Realization of data transfer among CPU registers, Main memory and Externalsources	9
5	Swapping of registers' contents	6
6	Control design	9

Core Lab/Pract – VI: Programming Paradigms Laboratory (CS2273)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Recursive Functions	3
2	Functional Programming using LISP	12
3	Object Oriented Programming using C++, Java, PHP	21

5th Semester

Core Theory – X: Microprocessor Based Systems (CS3101)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** A brief history of the Microprocessors: Development, advantages & use. Basic Architecture, Accumulator based, General Register and stack machines	1
2	**CPU Memory Interaction:** Basic facilities to carry out the interaction, BUSes, BUS operations, concept of I/O as a part of memory.	3
3	**H/W details of a typical Processor:** Functional and Pin by Pin description, Timing diagrams and machine cycles	4
4	**Assembly language Programming:** Processor Programming model, Instruction set and addressing modes, Assembler directives, Programming techniques and examples, Subroutines, Macros etc.	4
5	**Interfacing with Memory and I/O devices:** Address space (Memory and I/O), Decoders and decoding techniques, Use of ROM and PLA, Timing and other interfacing requirements, Buffers and transceivers etc.	5
6	**Interrupts:** What is interrupt, H/W and software issues, Interrupt lines, Priority, timing and context switch etc., Software interrupts, Vector and vector tables, Use of interrupts as OS entry points.	4
7	**Programmable Peripherals/Controllers:** PIO, PIC, Serial I/O controller, DMA	6
8	**Design of a small system:** Design of a system development kit, H/W requirement, Development of s/w modules, tools and supports for the development.	6
9	**Microcontrollers:** Architecture, Advantages, Programming model, Assembly Language, Use of microcontrollers in embedded design.	4
10	**Advanced microprocessors:** 16/32 processors, assembly language programming, Extra h/w and interrupt facility, Memory management, RISC and ARM processors	5
	Total	**42**

Core Theory – XI: Database Management Systems (CS3102)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Database and Database Management System:** Traditional File systems versus Database systems, database users, Role of DataBase Administrators (DBA), Concepts of the 3-level architecture, Features of DBMS.	2
2	**Informal Database Design** : High-level conceptual modelling, ER Modelling concepts, Cardinality constraints, Weak-entity types, Subclasses and inheritance, Specialization and Generalization.	3
3	**Relational Model, Languages and Systems:** Relational algebra**,** Relational Calculus, Relational model concepts, Relational integrity constraints, ER to relational mapping, Data definition, manipulation and related queries in SQL, Views, Integrity constraints.	5
4	**Formal Database Design:** Concept of functional dependencies, Normal forms	6

	based on Functional Dependency(FD), Multivalued Dependency and Join Dependency, Lossless decomposition, Dependency Preservation, Canonical cover of a set of FD.	
5	**Indexing Structures:** Basic terminologies, Different types of indexes, B-trees, B+ trees.	3
6	**Transaction Processing and Concurrency Control:** Concurrency issues, need for transactions, Transactions properties, Transaction states, Serializability, Locking, Deadlocks and starvation, Lock-based protocols, Timestamp-ordering based protocol,	5
7	**Database Recovery Techniques:** Recovery concepts, Deferred updates technique, Immediate update technique.	3
8	**Query Processing and Optimization:** Translating SQL into relational algebra, Basic query operations, Heuristics in query optimization, cost estimates in query optimization.	3
9	**Database Security and Authorization:** Discretionary access control, Mandatory access control and multi-level security, Statistical database security.	3
10	**Advanced Topics in DBMS:** Introductory overviews on Distributed Databases, Object Oriented Databases, NoSQL databases, etc..	3

Referred Books:

1. Database System Concepts – Silberschatz, Korth, and Sudarshan (McGraw Hill).
2. Fundamentals of Database Systems – Elmasri, and Navathe (Benjamin Cummings Publishing Company Inc.).
3. Principles of Database Systems – J. D. Ullman (Galgotia Publications (P) Ltd.).
4. Database Systems – C. J. Date (Addison Wesley).

Core Theory – XII: Computer Architecture and Organization – II (CS 3103)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** History of computing, the current need, technology road map, performance measure	2
2	**Instruction pipeline:** Pipeline hazards, structural hazards, data hazards, data forwarding, dynamic scheduling, control hazards, predict-taken predict-not-taken schemes, scheduling branch-delay slot, dynamic hardware prediction, exceptions, multi-path execution	10
3	**Cache design:** Cache, cache performance, cache updates, cache miss rate reduction, compulsory, capacity and conflict misses, hardware prefetching, compiler controlled prefetching, merging of arrays, loop interchange, loop fusion, blocking, reducing cache miss penalty, two-level caches, hit time reduction, avoiding address translation, cache coherence, protocols, directory based protocol, snooping, cache coherence in CMPs	10
4	**Instruction level parallelism:** Multiple issue processors; superscalar pipeline, pipeline scheduling, in-order issue, out-of-order issue, VLIW, compiler support for exploiting ILP, speculation, CMPs, SMPs	6
5	**Parallel computers:** Flynn's taxonomy, SIMD/MISD/MIMD machines, parallel and scalable architectures, multiprocessor system interconnects, multistage networks, dataflow versus control-flow, dataflow processors, static dataflow, dynamic dataflow, dataflow graph Introduction to Computing In-Memory architecture	12

Core Theory – XIII: Graph Algorithms (CS 3104)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction and review of graphs:** graphs and digraphs, subgraphs, representation of graphs, Graph traversal, complete graphs, regular graphs, Petersen graph, Bipartite graphs, Isomorphism of graphs. Walks, trails, paths, connected graphs, distance, cut-vertices, cut-edges, blocks, weighted graphs, connectivity, Minimum spanning tree, Single source & all pair shortest path.	6
2	**Network Flow:** The flow problem, flow and cut, Max flow min cut theorem, Ford Fulkerson, Shortest Path Augmentation algorithms	5
3	**Planarity of graphs:** Significance of planar graphs, Kuratowski's graphs, characterizing planar graphs – Euler's theorem, Planarity testing algorithms	5
4	**Matching and covering in graphs:** maximum matching; perfect matching; matching in bipertite graphs - Konig's theorem, Hall's marriage theorem; matching in general graph- Tutte's theorem; Path covering - Gallai-Milgram theorem, Dilworth theorem.	6
5	**Graph coloring:** Proper coloring of graphs, Chromatic number, algorithms for coloring, coloring of planar graphs, applications	4
6	**Large graphs:** Structural properties of large graphs – degree distribution, clustering coefficient, node centrality, Applications	6
7	**Design and Analysis of Algorithms for large graphs:** Ranking algorithms – PageRank, Community detection algorithms and their time complexity analysis, Applications	8
Total		40

Core Theory – XIV: Departmental Elective –I

Departmental Elective – I: Computer Graphics (CS3121)

Module /Sl.No.	Module Name and Topics	No. of Lectures
1	Overview, applications, pixels, aspect ratio, Object and background,4-neighbourhood and 8-neighbourhood, Representing images in 2-D arrays and files, Raster scan displays, Frame buffer and video controller	4
2	Straight line drawing algorithms, Circle generating algorithm, Ellipse generating algorithm, Arcs, Bezier curves and B-spline curves, Bezier surface and B-spline surface, Line styles.	8
3	Fill algorithm: Scan line polygon fill algorithm, boundary fill algorithm, flood fill algorithm, Soft filling, filling with patterns	2
4	Translation, rotation, scaling, reflection, shear, composite transformation, Viewing transformation.	6
5	Clipping operations: Point clipping, line clipping, polygon clipping.	4
6	Hidden surface removal methods	4
7	Colour models, basic illumination models transparency, intensity attenuation	2
8	Parallel projection and perspective projection, projection on an arbitrary plane	2
9	Animation: types, techniques, key frame animation, morphing, Virtual Reality concepts	2
10	Fractals preliminary	2

11	Image processing concepts	4

REFERENCES:
1. Donald Hearn and M Pauline Baker, “Computer Graphics C Version”, Pearson Education
2. Peter Shirley, Stephen R Marschner, Michael Ashikhmin, Michael Gleicher, Erik Reinhard, Kelvin Sung, and AK Peters, “Fundamental of Computer Graphics”, CRC Press.
3. Amrendra N Sinha and Arun D Udai, “Computer Graphics”, Tata MCGraw Hill.
4. D.P Mukherjee, “Fundamentals of Computer graphics & Multimedia”, PHI Learning Private Limited.

Departmental Elective – I: Web Technology (CS3122)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Course overview and basic HTML/CSS**	3
2	JavaScript	6
3	Serverside Scripting Language PhP, NodeJs	9
4	Intro to Document Object Model,	3
5	Intro to XML and AJAX	3
6	HTTP protocol	3
7	**Simple Object Access Protocol (SOAP)**	3
8	**Web Services, REST**	3

Departmental Elective – I: Soft Computing (CS3123)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Overview:** Motivation, Computational Intelligence	1
2	**Fuzzy Sets and Systems:** Crisp set and Fuzzy set, Membership functions, Operations on fuzzy sets, Properties of fuzzy sets, Fuzzy Relations, Fuzzy Measures, Fuzzy Arithmetic, Fuzzy extension principle, Approximate Reasoning, Fuzzy implication functions, Fuzzy Inference Systems, Type-2 fuzzy sets, Applications.	8
3	**Artificial Neural Networks:** Fundamental concepts of neural networks, Basic models and learning rules, Supervised learning, Perceptron Learning Rules, Back propagation network, Unsupervised learning, Hebbian learning, Self-Organizing feature map, Radial Basis function network, Recurrent neural network, current topics: Deep Learning, Applications.	9
4	**Optimization methods** *Genetic Algorithms*: Basic concepts of genetic algorithms, encoding, Genetic Operators, Fitness function, genetic modeling, Applications *Particle Swarm Optimization:* Basic Concepts, Local Best, Global Best, Velocity Updation, Position Updation, Variant of PSO, Applications Differential Evaluation: Basic Concept, Initialization of vectors, Target Vector, Donor Vector, Selection, Mutation, Crossover, Control Parameters, Applications Ant colony optimization and current topics	8
5	**Rough Set Theory:** Decision Systems, Indiscernibility Relation, Inconsistency, Lower and Upper Approximation, Rough Set, Attribute dependency, Attribute Reduction, Discernibility matrix, Reduct and Core, Applications of Rough Set Theory:- dimensionality Reduction, Feature	5

	Selection, Classifier.	
6	**Hybrid Systems:** Neuro-Fuzzy systems, Rough -fuzzy and Fuzzy-rough sets, Optimization-learning Algorithms, Applications in Image Processing, Bioinformatics, Expert Control Systems	4

Core Lab/Pract–VIII: Microprocessor Based Systems Laboratory (CS3171)

Module / Sl.No.	Module Name and Topics	No. of Lectures
1	Familiarisation I (H/w) 8 bit / 16 bit INTEL microprocessor with SDK (Functional blocks, Major ICs used, Memory Map, Decoding circuit, special h/w facilities etc.) + Data and Command keys, Commands, etc.	3
2	Familiarisation II (S/w) Hand assembly and loading and execution of simple programs.	3
3	I/O : Programming, Memory and I/O mapped I/O; PPI and using PPIs	3
4	Procedures/Functions and use of stack	3
5	Programming/Debugging: H/W and S/W facilities: Implementation of complex algorithms and use of debugging methods, Recursive routine, Stack based parameter passing	9
6	Serial I/O: Downloader (loading the object file from computer to SDK)	3
7	Interrupt: Test a keyboard Interrupt and a Timer/Counter interrupt	3
8	Familiarization followed by Design and Development of a small system using Raspberry PI/ Arduino/ 8051 Microcontroller family,	9

Core Lab/Pract–IX: Database Management Systems Laboratory (CS3172)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Structured Query Language (SQL): **DDL:** Creating Tables, Specifying Relational Data Types, Specifying Constraints, DROP, ALTER, TRUNCATE. **DML:** INSERT statement, The SELECT statement, Use of SELECT and INSERT together, DELETE, UPDATE, Creating Column Aliases, WHERE clause, Using Logical Operators in the WHERE clause, IN, BETWEEN, LIKE , ORDER BY, GROUP BY and HAVING Clause, Aggregate Functions, Combining Tables Using JOINS, Subqueries – independent and correlated, From clause subqueries. **DCL:** Creating Database Users, Using GRANT and REVOKE. **VIEWS**: Creating Views, data handling using views.	24
2	Writing Oracle PL / SQL code blocks, Cursors and Trigger in Oracle PL / SQL, Writing Oracle PL / SQL Stored Procedures.	15

Core Lab/Pract–X: Departmental Elective – I Laboratory

Departmental Elective – I: Computer Graphics Laboratory (CS 3181)

Module / Sl.No.	Module Name and Topic	No. of hours
1	Setting up mapping between screen coordinate and conventional cartesian coordinate, Grid formation.	3
2	Straight line using different line drawing methods	6
3	Circle using midpoint algorithm	3
4	Ellipse using midpoint algorithm	3
5	Area filling: - Flood fill algorithm, Boundary fill algorithm	6
6	Geometric transformation	3
7	Clipping of a polygon	3
8	Bezier and Spline curve drawing	3
9	Hidden Surface removal, Rendering, Illumination, Animation, Fundamentals of image processing	9

Departmental Elective – I: Web Technology Laboratory (CS3182)

Module / Sl. No.	Module Name and Topics
1	Assignment covering all the topics in the syllabus

Departmental Elective – I: Soft Computing Lab (CS3183)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Introduction to MATLab Tool box	3
2	Fuzzy Logic- Designing of Membership Function, Fuzzy Rule Base for handling Uncertain knowledge based systems, Fuzzy Inference Engine, Defuzzification, Fuzzy C-means Clustering, Visualization of results	12
3	Artificial Neural Network- Designing Architecture of ANN, Feeding Input-Output Patterns, Training using Back propagation Algorithm, Training using SOM, Classification, Pattern Recognition	12
4	Evolutionary Algorithms- Implementation of GA and PSO for optimizing Benchmark functions, Clustering using GA, Designing Hybrid Systems.	10

6th Semester

Core Theory – XV: Operating Systems (CS3201)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** Definition, Early systems, Simple batch systems,	2

	Multiprogrammed batched systems, Time-sharing/Multi-tasking systems, Personal-Computer systems, Multiprocessor systems, Distributed systems, Clustered System, Real-Time systems	
2	**Overall Structure:** OS as layers and modules within layers implementing System Call Interface	2
3	**Process Management:** Process concept, Process scheduling, Operation on processes, Cooperating processes, Interprocess Communication, Concept of Thread	6
4	**CPU Scheduling:** Basic concept, Scheduling criteria, Scheduling algorithms, Multiple-Processor Scheduling, Real-Time scheduling	2
5	**Process Synchronization:** Critical-Section problem, Synchronization hardware, Semaphores, Critical regions, Monitors	4
6	**Deadlocks:** Deadlock characterization, Methods for handling deadlocks, Deadlock prevention, Deadlock avoidance, Deadlock detection and Recovery.	4
7	**Memory management:** Logical vs. physical address space, Swapping, Contiguous allocation, Paging, Segmentation, Segmentation with paging.	4
8	**Virtual memory:** Demand paging, Performance of demand paging, Page replacement, Page-Replacement algorithms, Allocation of frames, Thrashing, Demand segmentation.	4
9	**IO Subsystem:** IO Hardware, Character and Block devices and IO interface	2
10	**File-System Interface:** File concept, Access methods, Directory structure, Protection.	2
11	**File-System Implementation:** File System structure, Allocation methods, Free-Space management, Directory Implementation, Efficiency and Performance, Recovery.	2
12	**Secondary storage structure:** Disk scheduling, Disk management, Swap-space management.	2
13	**Protection:** Goals of protection, Domain of protection, Access matrix, Implementation of access matrix, Revocation of access rights, Capability-Based systems.	2

Core Theory – XVI: Data Communication and Computer Network (CS3202)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** Layered Network Protocol Architectures; Personal, Local, Metropolitan and Wide Area Networks; Telecommunications and Cellular Networks overview. Message transport: Circuit, message and packet switching, Topological design.	6
2	**Physical Layer and communication:** Analog Signal – Sine wave, Phase, Wavelength, Time and Frequency Domain, Composite Signals and Bandwidth; Digital Signal – Bit rate and length, Digital signal as a composite analog signal; Elements of electronic communication systems, Parallel and Serial Transmission, RF spectrum; Transmission Impairment – Attenuation, Interference, Distortion, Noise; Important terms – Throughput, Latency, Jitter; Limitation of electronic communication systems (Nyquist Bit Rate, Shannon Capacity). **Transmission Media:** Guided media : Twisted-Pair, Coaxial Cable and Fiber-optic cable. Unguided media : Propagation methods, Radio Waves, Microwaves, Infrared. **Waveform coding techniques:** Pulse Code Modulation (PCM), Line coding, Line coding schemes, Scrambling.	14

	Modulation techniques: Review of Analog Modulation schemes (AM, FM, PM). Digital Modulation - ASK, FSK, PSK, QAM, Binary and M-ary signalling techniques & their spectra. **Advanced Digital communication techniques:** Spread Spectrum Modulation, Orthogonal Frequency Division Multiple Access	
3	**Data Link Layer and Logical Link Control (LLC) sub-layer:** Framing; Error control including Bit-parity, CRC and Hamming Codes; Reliable transmission and Automatic Repeat Request (ARQ) protocols including Stop-and-Wait, Go-back-N, Selective Repeat. Performance analysis of ARQ protocols. Example protocols such as HDLC and PPP.	5
4	**Medium Access Control (MAC) sub-layer:** Shared media systems; Bus, Star and Ring topologies; TDMA, FDMA, CSMA, CSMA/CD, Ethernet and IEEE 802.3; IEEE 802.11 including CSMA/CA protocols;	5
5	**Network Layer:** Internet Protocol (IP) suite; Hierarchical network architectures; IPv4 and IPv6 addressing and headers; Related protocols ICMP, IGMP, ARP, RARP, BOOTP, DHCP. Routing protocols including distance-vector and link-state approaches; Interior and Exterior Gateway Protocol concepts; Routing Algorithms including Dijkstra's algorithm and distributed Bellman-Ford algorithm; Example protocols: OSPF, RIP, BGP.	10
6	**Transport Layer:** Reliable end-to-end transmission protocols; UDP header; Details of TCP header and operation including options headers, Error Control, Flow control and Congestion control;	7
7	**Application Layer:** Socket Interface and Socket programming; Example protocols such as DNS, SMTP, FTP, and HTTP.	3

Core Theory – XVII: Software Engineering (CS 3203)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** Concept and types of systems – organizational system, software system, information system. Need for software engineering	2
2	**Life cycle models and process:** Traditional models - Waterfall model, rapid prototype model, evolutionary model, V model; Agile model - Extreme Programming(XP), Scrum; Secure Software Development Lifecycle	5
3	S**oftware requirements specification**, formal requirements specification and verification - axiomatic and algebraic specifications	3
4	**Software design:** System Models, Architectural Design, Abstraction & Modularity. Traditional approach - Structured Analysis and Design, Structure charts; Object-oriented approach, UML diagrams, Service Oriented Architecture, User Interface Design	12
5	**Software Testing and Maintenance:** Black box and white box testing methodologies; Unit, Integration, System testing. Computer-aided software engineering (CASE), software reuse.	6
6	**Software project management:** Software size and cost estimation (LOC, Function point, COCOMO), Software project Planning, Scheduling, Monitoring, and Control. Configuration management	6
7	**Software Reliability and fault-tolerance**	4

	Quality Assurance: Metrics of software reliability and quality, reliability testing. **Quality systems** - ISO, CMM, Six Sigma.	

Core Theory – XVIII: Information Security and Cryptography (CS 3204)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Overview of Information Security** Basic components, Security goals, Threats, Policy and mechanism, Assumptions and trust, Assurance, Operational issues, Human issues, Security life-cycle	4
2	**Information Security Models** Protection state, Access control matrix model, Protection state transitions, Copying/Owning/Attenuation of privilege, Take-Grant protection model	6
3	**Security Policies** Security policies, Types of security policies, Role of trust, Types of access control, Policy language, Confidentiality and integrity policies and models, Access control policies	8
4	**Basic Concepts & Techniques of Cryptography** Introduction, Plaintext and cipher text, Cryptographic techniques, Encryption and decryption, Mathematical foundations of cryptography.	4
5	**Symmetric & Asymmetric Key Algorithms** Introduction, Algorithm types & modes, Symmetric- & asymmetric-key ciphers, Key range & sizes, Symmetric key algorithms (e.g., DES, AES, Diffie-Hellman, ECC), Asymmetric key algorithms (e.g., RSA, El Gamel)	8
6	**Other Aspects of Security** Message integrity, Message authentication, Digital signature, Certification Authority, Digital certificate, Key management	6

References / Books:

1. "Computer Security: Art & Science", Matt Bishop, *Addison Wesley*.
2. "Cryptography and Network Security", William Stallings, 2nd Edition, *Pearson Education Asia.*
3. "Network Security private communication in a public world", C. Kaufman, R. Perlman and M. Speciner, *Pearson.*
4. "Cryptography & Network Security", Atul Kahate, *TMH.*
5. "Designing Network Security", Merike Kaeo, 2nd Edition, *Pearson Books*.

Core Theory – XIX/ Departmental Elective -II

Departmental Elective – II: Nature-Inspired Algorithms (CS3221)

Module / Sl. No.	Module Name and Topics	No. of Lectures
	Introduction	
1	Overview of Optimization: Optimization, Objective Function, Decision Variables, Decision Space, Constraints, State Variables, Local and Global Optima, Near-Optimum Solutions. Introduction to Meta-Heuristic Algorithms: Definition of Terms of the Meta-	1

2	Heuristic Algorithms, Classification of Nature-Inspired Algorithms, Principles of Meta-Heuristic and Evolutionary Algorithms, Generating Random Values of the Decision Variables, Fitness Function, Selection of Solutions, Generating New Solutions, The Best Solution, Termination Criteria, Performance Evaluation, Search Strategies.	3
	Biology-Based Algorithms	
3	*Evolutionary Algorithms (EA*): Genetic Algorithms (GA): Encoding Schemes, Selection, Crossover, Mutation, Termination Criteria, Pseudo Code for GA, Convergence Analysis of GA, Applications.	5
4	Differential Evolution (DE): DE Fundamentals, Creating Initial Population, Generating Trial Solutions, Mutation, Crossover, Greedy Criterion, Termination Criteria, Pseudo Code of DE, Applications	2
5	*Bio-Inspired Algorithms (BIA):* Particle Swarm Optimization (PSO): Creating an Initial Population of Particles, The Individual and Global Best Positions, Velocities of Particles, Updating Positions of Particles, Pseudo Code of the PSO, Variants of PSO, Convergence Analysis of PSO Algorithms, Applications.	3
6	Egyptian Vulture Algorithm (EVA): History and Life Cycle of Egyptian Vulture, Egyptian Vulture Optimization Algorithm, Applications.	1
7	Shuffled Frog Leap Algorithm (SFLA): Mapping Memetic Evolution to Frogs to Shuffled Frog Leaping Algorithm, Creating an Initial Population, Classifying Frogs into Memeplexes, Frog Leaping, Shuffling Process, Pseudo Code of the SFLA.	1
8	Invasive Weed Optimization (IWO): Mapping Invasive Weed Optimization to Weeds' Biology, Creating an Initial Population, Reproduction, The Spread of Seeds, Eliminating Weeds with Low Fitness, Termination Criteria, Pseudo code of the IWO.	1
9	Plant Propagation Algorithm (PPA): Mapping of Natural Process to the PPA, Creating an Initial Population of Plants, Normalizing the Fitness Function, Propagation, Elimination of Extra Solutions, Termination Criterion, Pseudo Code of the PPA.	1
10	Kidney Inspired Algorithm (KIA): Motivation, KIA Algorithm, Applications.	
11	*Swarm Intelligence-Based Algorithms (SIA):* Ant Colony Optimization (ACO): Biological Inspiration, Creating an Initial Population, Allocating Pheromone to the Decision Space, Generating of New Solutions, Termination Criteria, Pseudo Code of the ACO, Variants of Ant Colony Optimization, Applications.	2
12	Artificial Bee Colony (ABC): Biological Inspiration, Swarm Behaviour, ABC Algorithm, Various Stages of ABC Algorithm.	4
13	Bat Algorithm (BatA): Biological Inspiration, Bat Algorithm, Applications.	
14	Firefly Algorithm (FA): Mapping the Firefly Algorithm to the Flashing Characteristics of Fireflies, Creating an Initial Population, Attractiveness, Distance and Movements, Pseudo Code of the FA.	
15	Cuckoo Search (CS) Algorithm: Traditional Cuckoo Search Optimization Algorithm, Variants of Cuckoo Search Algorithms, Applications.	
	Physics Based Algorithms	
16	Gravitational Search Algorithm (GSA): Physics of Gravity, Gravitational Search Algorithm, Parameters of GSA, Fitness Function, Variants of GSA,	3

	Hybrid GSA, Wide Varieties of Applications of GSA.	
17	Central Force Optimization (CFO): Central Force Optimization Metaphor, CFO Algorithm, Decision Space and Probe Distribution, Variants of CFO, Applications.	2
18	Harmony Search (HS) Algorithm: Inspiration of the HS, Harmony Memory, Harmony Search Algorithm, Updating Harmony Memory, Stopping Condition, Characteristic Features of Parameters in the HS Algorithm, Variants of HS Algorithm, Applications.	2
19	Big Bang – Big Crunch (BB-BC) Algorithm: Inspiration and Algorithm, Applications.	5
20	Black Hole (BH) Algorithm: Inspiration and Algorithm, Applications	
21	Galaxy-Based Search Algorithm (GBS): Inspiration and Algorithm, Applications.	
22	Water Cycle Algorithm (WCA): Inspiration and Algorithm, Variants of WCA, Applications.	
23	River Formation Dynamics (RFD): Inspiration and Algorithm, Applications.	
	Chemistry Based Algorithm	
24	Chemical Reaction Optimization (CRO): Mechanism of Chemical Reaction, CRO, Variants of CRO, Hybrid CRO, Applications of CRO.	2
25	Artificial Chemical Reaction Optimization (ACRO) Algorithm: Inspiration and Algorithm, Applications.	1

Text Books and References:

1. Meta-Heuristic and Evolutionary Algorithms for Engineering Optimization, Omid Bozorg-Haddad, Mohammad Solgi and Hugo A. Loaiciga John Wiley & Sons
2. Discrete Problems in Nature Inspired Algorithms, Anupam Shukla and Ritu Tiwari, CRC Press
3. Nature-Inspired Computing, Physics and Chemistry-Based Algorithms, Nazmul Siddique and Hojjat Adeli, CRC Press, Plus, Relevant Recent Journal Papers.

Departmental Elective – II: Bioinformatics (CS3222)

Module / Sl No	Module Name and topics	No. of Lectures
1	**Basic of Bioinformatics:** Introductory Molecular Biology, Genomics - information flow in biology, DNA sequence data, Structure and properties of different forms of DNA and RNA, DNA replication, Examples of related tools (FASTA, BLAST, BLAT, RASMOL), databases(GENBANK, Pubmed, PDB) and software(RASMOL, Ligand Explorer)	4
2	**Nature of biological data:** Introduction & overview of Biological databases, Major Bioinformatics Resources: Nucleic acid databases (NCBI, DDBJ, and EMBL). Protein databases (Primary, Composite, and Secondary). Specialized Genome databases: (SGD, TIGR, and ACeDB). Structure databases (CATH, SCOP, and PDBsum)	4
3	**Data storage and retrieval and Interoperability**: Flat files, relational, object oriented databases and controlled vocabularies. File Format (Genbank, DDBJ, FASTA, PDB, SwissProt), Methods for presenting large quantities of biological data: sequence viewers (Artemis, SeqVISTA), 3D structure viewers (Rasmol, SPDBv, Chime, Cn3D, PyMol), Anatomical visualization.**;** Introduction to Metadata and search; Indices, Boolean, Fuzzy, Neighboring	5

	search. The challenges of data exchange and integration. Browsing and Querying, Query Processing-Semantics, planning and optimization, Complex Query-The Ontology, Exploring the Ontology, Biological Ontologies-TAMBIS	
4	**Sequence Alignments and Visualization**: Introduction to Sequences, alignments and Dynamic Programming; Local alignment and Global alignment (algorithm and example), Pairwise alignment (BLAST and FASTA Algorithm) and multiple sequence alignment (Clustal W algorithm).	5
5	**Protein sequence databases:** Functional Proteomics - protein sequence and structural data, Basic aspects of protein conformation, protein synthesis transcription (mRNA processing), translation (activation of amino acids, initiation, elongation, termination & release of peptides), post-translational modification of proteins, Computational & biological data analysis-Searching and Mining, sequence data bases, NCBI model, file format.	5
6	**Genome Analysis:** Introduction, Gene prediction methods, Gene mapping and applications- Genetic and Physical Mapping, Integrated map, Sequence assembly and gene expression data, Introduction of Genome Annotation, DNA Microarray for analysis of single nucleotide polymorphism using DNA chips.	6
7	**Protein sequence Analysis:** Prediction of various secondary & tertiary structure of proteins, Hydropathy profiles, Post-translational modifications, Modeling	5

Departmental Elective – II: Computing-in-Memory Architecture (CS3223)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** History of computing, the current need, technology road map, performance measure, Continuum computer for exaflops computation	4
2	**Todays computers:** Introduction to von Neumann architecture, Pipelining datapath and instructions - speed up, Memory hierarchy – virtual memory system, content addressable memory (CAM), Data intensive applications, Computing walls - power wall, memory wall, ILP wall, Technology walls - leakage, reliability, cost, CPU-Centric/Data-Centric computing – data-centric approaches, Heterogeneous architectures – accelerators, specialised logic, Near-Memory computing architectures – requirements, challenges, programming model, data mapping, In-Memory computing architectures – computational RAM, PIM, CIM	10
3	**Computation-In Memory:** Background, CIM model, Logic and core architecture, Programming CIM, Interactions between von Neumann and CIM models, In-memory computing with resistive switching devices - computational memory technologies, digital computing by binary resistive switching, computing by cumulative resistive changes,	6
4	**Memristor:** Potential applications - Non-Volatile memory, logic gates, Computing - resistive, neuromorphic and biological, Memristor based memories, Memristor based CIM architecture - micro-architecture, ISA, programming model, execution model, Compiler - supporting complex operations, compiler optimizations	5

5	**Memristor for CIM:** Boolean logic, Circuit design concepts, Implication logic, Majority logic, Threshold logic, Complementary logic, Adder/subtractor/decade counter/...., Parallel input-processing memristor logic, Memristor based content addressable memory, Memristor-based storage structures, Memristive devices for vector processing, Energy efficiency of memristive logic families - energy of In-Memory logic families, Near-Memory logic families, Out-of-Memory logic families, Area evaluation – CMOS memristor system integration challenges	6
6	**CIM for data analytics:** Matrix multiplication on CIM architecture, algorithms - CIM model of parallel computation, Parallel cost model - mapping cost, computational cost, communication cost, readout cost, CIM for signal, image and video processing, machine learning - deep learning inference for IoT sensory applications, Brain-inspired hyper-dimensional computing	5
7	**Technology:** Memristive materials and nanoscale devices - anion devices, cation devices, physical switches, device geometries, Nonlinear switching dynamics, Prospective applications	4

Departmental Elective – II: Graph Theory (CS3224)

Module / Sl No	Module Name and topics	No. of Lectures
1	**Introduction:** Definition and Application of Graphs, Finite and Infinite graphs, Incidence and degree, Isolated and pendant vertex, Null graphs.	2
2	**Paths and Circuites:** Concept of Graph Isomorphism and Subgraphs; Definition of walks, paths and circuits; Connected and disconnected graphs; Components; Euler graphs, Hamiltonian Paths and Circuits. The travelling salesman problem	4
3	**Trees and fundamental circuits:** Trees; Properties of a tree; Distance and centre in a tree; rooted and binary trees; Counting trees; Spanning trees; Finding spanning trees in weighted graphs	6
4	**Special classes of graphs:** Bipartite graphs, line graphs, chordal graphs	2
5	**Cut set and verticess:** Cut sets and their properties; finding all cut sets in a graph; fundamental circuits and cut sets; connectivity and seperability; Network flows.	6
6	**Planner and Dual Graphs:** Combinatorial vs geometric graphs; Planner graphs; Kuratowsk's two graphs; Detection of planarity; geometric and combinatorial dual; Different representation of planner graphs.	6
7	**Representation Graph:** Incidence matrix; Adjacency matrix and list; Path matrix; cut set matrix.	2
8	**Graph Coloring:** Chromatic number; Chromatic partitioning; Chromatic polynomial; matching; covering; The four color problem.	4
9	**Independent sets, coverings, matchings:** Basic equations, matchings in bipartite graphs, perfect matchings,	4
10	**Directed graph**: Definition and types; Digraphs and binary relations; directed paths and connectedness; Euler digraph; trees with directed edges; fundamental circuits and Digraphs.	4
11	**Graph theoretic Algorithms and computer program:** traversal algorithms; connectedness and components; spanning trees; a set of fundamental circuits; cut vertex and reparability; Shortest path algorithms; Planarity testing algorithms etc(home assignmemts to be given)	6

Lab – XI: Operating Systems Laboratory (CS3271)

Module / Sl No	Module Name and topics	No. of Lectures
1	Assignment on bootstrap loader.	3
2	Assignment on usage of process related system calls.	3
3	Assignment on usage of Inter Process Communication (IPC – shared memory, pipe, semaphore, message queue) system calls	6
4	Simulation of different Scheduling and Deadlock related algorithms.	6
5	Assignment on usage of file system related system calls (files and directories)	3
6	Assignment on implementation of file system module of operating system	9
7	Implementation of a Shell	9

Lab – XII: Computer Network Laboratory (CS3272)

Module / Sl No	Module Name and topics	No. of Lectures
1	Assignments on TCP / IP socket programming	9
2	Implementation of upper layer (layer 3 and above) protocols on raw socket interface provided by Linux	9
3	Study of the departmental and campus LAN to identify the components implementing different layers of OSI model and different protocols of those layers	6
4	Familiarization with different network management tools	8
5	Implementation of a physical LAN and different network related services	8

Lab – XIII: Software Engineering Laboratory (CS3273)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Understanding and specification of requirements for real-world problem	6
2	Object-oriented design, open source tools for UML modelling	9
3	Tools for coding, documentation	6
4	Tools for testing software – static analysis, dynamic analysis, detecting	9
5	Configuration Management / version control systems	3
6	Tool for Project management, Scheduling and Tracking	3

7th Semester

Core Theory – XX: Compiler Design (CS4101)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Review of languages and grammars, Interpreter model -- basic concepts, Translator model- Assembler, Compiler, Applicability of Interpreter and	2

	translator models.	
2	Design of Single pass and Two pass assemblers, MACRO and MACRO processor	5
3	Design of Compiler, 2-phase process. Analysis Phase, Synthesis phase	1
4	Scanner -- The scanning process, Design using finite state m/cs, Scanner generator (LEX).	3
5	Parsing -- Top-down and bottom-up strategies: general considerations	1
6	Top-down parsing-- Brute-force approach, LL(1), Recursive descent	5
7	Bottom-up parsing -- Operator precedence parser	2
8	Bottom-up Parsing -- LR grammars -- LR(0), SLR(1), canonical LR(1) and LALR(1) parsers. Comparison of Parsing methods. Parser Generator (YACC).	5
9	Symbol tables -- organisations for non-block structured languages (unordered/ordered/tree/hash) and block structured languages (stack tables and stack implementations)	1
10	Runtime storage management -- static allocation; dynamic allocation -- activation records and their usage, recursive procedures. Heap allocation -- storage request and release strategies.	2
11	Semantic analysis -- basic concepts; attributed translation; Intermediate codes; Syntax directed translation concepts.	5
12	Code optimization: machine dependent optimization, m/c independent optimization- local and global optimization, optimizing transformations, basic block and DAG for local optimization, Data flow analysis for global optimization. machine dependent optimization.	5
13	Code generation	3

Reference Book:

1. Alfred V. Aho, Ravi Sethi,Jeffrey D Ullman,"Compilers Principles Techniques and Tools", Pearson Education.

Core Theory – XXI: Machine Learning (CS 4102)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Overview: Motivation, Introduction of Machine Learning, Types of Machine Learning	3
2	Mathematics: Probability, Bayes' rule, conditional probability, likelihood, hyperparameters, Bayesian method, Polynomial Models, Linear algebra	6
3	Supervised learning: Regression Models, Support vector machines, Generative/discriminative learning, parametric/nonparametric learning, Multolayer Perceptron neural models, Gradient descent, Backpropagation, Batch processing, Learning rate, Cross validation, Overfitting, Regularization, Radial Basis function neural network, Principal component analysis	10
4	Unsupervised learning: clustering, Kohonen Network, SOFM, dimensionality reduction, kernel methods; Advanced discussion on clustering and Gaussian Mixture Models, Expectation Maximization	6
5	Reinforcement learning: Mathematical Formulation, Markov decision process	3
6	Deep Learning Models: RBM, Autoencoder, CNN, Transfer Feature Learning of CNN, RNN, LSTM, GRU, GAN, Different types of GANs, Ensemble methods	10
7	Intelligent Machines	2
	Total	40

Reference Books:

1. A Course in Machine Learning by Hal Daumé III
2. Pattern Recognition and Machine Learning by Chris Bishop (ISBN 0387310738)
3. Deep Learning (Adaptive Computation and Machine Learning series) by Ian Goodfellow, Yoshua Bengio, Aaron Courville, Francis Bach, 2017
4. Machine Learning by Tom Mitchell (ISBN 0070428077)
5. Elements of Statistical Learningby Trevor Hastie, Robert Tibshirani and Jerome Friedman (ISBN 0387952845)

Core Elective – I: Departmental Elective – III

Departmental Elective – III: Embedded Systems (CS4121)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction** Concept of embedded system, types of embedded system, Types of signals and systems, Processors and hardware units for embedded system, embedded software, hardware – software co-design, system on chip	4
2	**System specification and system analysis** Requirements, embedded system analysis, modeling techniques, performance metrics	4
3	**System design techniques** Traditional approach, design philosophy, hardware software partitioning, system architecture, hardware synthesis, software design, optimization (energy, space, time) issues, POLIS co-design methodology	8
4	**Implementation platforms** Microcontrollers, DSP, PIC, FPGA	6
5	**Real time issues** System monitoring, RTOS, clock synchronization, wireless devices, parallelism	5
6	**Fault tolerance techniques** Fault tolerant design principles, redundancy in hardware software, testing of embedded system, time and data. Byzantine algorithm, Multi-module embedded system	5
7	**System design Case studies** Algorithm, Controller and comprehensive system design	8

Departmental Elective – III: Digital Image Processing (CS4122)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** Importance and use of DIP, Historical perspective, Development and present state.	2
2	**Acquisition, Representation, Storage:** Sampling, Quantization, Basic Relationship Between Pixels and their neighborhood properties. Image types, Representation of image for processing and File formats.	4
3	**Image enhancement in spatial domain:** Gray-level transformations, histogram equalization, spatial filters- averaging, order statistics; Edge detection: first and second derivative filters	4

4	**Image filtering in frequency domain:** One and two-dimensional DFT, properties of 2-D DFT, periodicity properties, convolution and correlation theorems, Fast Fourier Transforms, Smoothing and sharpening filtering in frequency domain, ideal and Butterworth filters, homomorphic filtering	6
5	**Colour Image Processing**: Color models, Pseudo-color image processing, Color transformation.	3
6	**Morphological Image Processing:** Dilation, Erosion, Opening, Closing, Hit-or-miss Transformation, Some basic morphological Algorithms – Boundary Extraction, Region filling, Convex Hull etc	3
7	**Image segmentation:** Edge linking and boundary detection, Hough transforms, graph-theoretic techniques, global and adaptive thresholding, Region based segmentation,	5
8	**Shape Representation and Description:** Chain codes, polygonal approximation, signatures skeletons, shape numbers, Fourier descriptor, statistical moments, topological descriptor, texture	4
9	**Image Compression:** Redundancies, Image compression models, loss-less compression, lossy compression	4
10	**Tools:** Introduction to MATLAB IP functions and their use	2

Departmental Elective – III: Mobile and Pervasive Computing (CS4123)

Module / Sl. No.	Module Name and Topics	No. of Lectures
	Part-I: Mobile Computing	
1	Cellular networks: Introduction, frequency reuse, cell design, cellular architecture, channel assignment, hand-off strategies, location tracking, mobility management, task offloading, capacity improving methods, user validation.	6
2	Cellular Network Standards: System architecture, Protocol layers, services and features (GSM, IS-95), overview of 5G/6G	6
3	Mobile IP: Architecture, Agent discovery, Registration, Tunneling, Security & Privacy	4
	Part-II: Pervasive Computing	
5	Introduction to Pervasive Computing, History, Applications; Location-based service, Service discovery, Context-aware computing, Energy harvesting	9
6	Device Technology - sensing, actuation, compute modules; Internet of Things (IoT), Edge/Fog computing, Wearable computing; Connectivity protocols - Bluetooth, WiFi, WiMAX, ZigBee, etc.	6
7	Infrastructure and middleware of pervasive computing - middleware, programming, mobility and adaptation.	5

Course Objective: The course aims at providing a sound conceptual foundation in the area of Pervasive Computing aspects. It attempts to provide a balanced treatment of the mechanisms and environments of mobile and pervasive computing. The course should motivate studentsto explore the state-of-the-art in the area. At the end of this course, students should be able to conceptualize, analyze and design select classes of pervasive computing systems.

Prerequisite: Knowledge about EM spectrum including radio wave, fundamentals ofdigital communication and computer networks.

Text and Reference Books:

1. Wireless Communications Principles and Practice, Theodore S. Rappaport, PH (PTR)
2. Mobile Cellular Telecommunications, William C. Y. Lee, Tata McGrawHill
3. Wireless Communications and Networks, William Stallings, Pearson
4. Mobile Communications, Jochen Schiller, Pearson
5. Mobile Computing, S. DasBit and B.K. Sikdar, PHI
6. Pervasive Computing: Technology and Architecture of Mobile Internet Applications, J. Burkhardt, H. Henn,S. Hepper, T. Schaec & K. Rindtorff, Pearson
7. Fundamentals of Mobile and Pervasive Computing, F. Adelstein, S K S Gupta, GG Richard & L Schwiebert, Tata McGraw-Hill

Departmental Elective – III: Natural Language Processing (CS4124)

Module / Sl. No	Module Name and Topics	No. of Lectures
1.	**Introduction:** Human languages, Phases in natural language processing, classical problems, text representation in computers, encoding schemes.	2
2	Review of Regular Expressions, CFG and different parsing techniques	2
3	**Morphology:** Inflectional and Derivational Morphology, Finite State Morphological Parsing, The Lexicon and Morphotactics, Morphological Parsing with Finite State Transducers, Orthographic Rules and Finite State Transducers.	2
4.	**Language Models:** Introduction to N-grams, Chain Rule, Smoothing – Add-One Smoothing, Witten-Bell Discounting; Backoff, Deleted Interpolation, Evaluation of language models .	4
5	**POS Tagging:** A survey on natural language grammars, Tag sets, concept of HMM tagger, rule based and stochastic POST, algorithm for HMM tagging, transformation based tagging **Sentence level construction & unification:** Noun phrase, co-ordination, sub-categorization, concept of feature structure and unification.	6
6	**Representing Meaning:** Unambiguous representation, canonical form, expressiveness, meaning structure of language, basics of FOPC **Semantic Analysis:** Syntax driven, attachment & integration, robustness **Lexical Semantics:** Lexemes (homonymy, polysemy, synonymy, hyponymy), WordNet, internal structure of words, metaphor and metonymy and their computational approaches **Word Sense Disambiguation:** Selectional restriction based, machine learning based and dictionary based approaches.	8
7	**Natural Language Generation:** Introduction to language generation, architecture, discourse planning (text schemata, rhetorical relations). Standardization using Unicode and Code Conversion.	4
8	**A Few Applications** - Spell-checking, Summarization, Machine based Translation	4

Departmental Elective – III: Internet of Things (CS4125)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Introduction to Internet of Things & Cloud Computing:	10

	Architectural Overview; Design principles and needed capabilities; Basics of Networking - M2M and IoT technology fundamentals - devices and gateways; Data management; Business processes in IoT; Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.	
2	Software and Hardware Components of IoT Components: Hardware Components- computing (Node MCU, Raspberry Pi, etc.), communication, sensing, actuation, I/O interfaces; Software Components - programming APIs (using Python/Node.js/Arduino), communication and application protocols (e.g., MQTT, ZigBee, BLE);	10
3	IoT Application Development: Solution framework for IoT applications- Implementation of Device integration; Data acquisition and integration; Device data storage- Unstructured data storage on cloud/local server; Authentication, authorization of devices.	10
4	Case Studies: IoT case studies: Industrial automation /Transportation/Agriculture/Healthcare/Home Automation	6

Reference Books:

1. Vijay Madisetti, Arshdeep Bahga, "Internet of Things - A Hands on Approach", University Press.
2. Cuno Pfister, "Getting Started with the Internet of Things", O Reilly Media.
3. Gautam Shroff, "Enterprise Cloud Computing: Technology, Architecture, Applications", Cambridge Press.

Open Elective – I

Open Elective – I: HSS - III

Lab – XIV: Compiler Design Laboratory (CS4171)

Module / Sl. No.	Module name and topics	No. of Lectures
1	Familiarization with LEX and design of Lexical Analyzer	6
2	Familiarization with YACC	3
3	Declaration Processing and Type Analysis	3
4	Generation of three-address code for assignment statement	3
5	Writing functions required to handle Boolean expression	3
6	Generation of three-address code for *if and if-else* and while statement	6
7	Generation of three-address code for *for* statement and procedure/function call	6
8	Generation of three-address code for array handling	3
9	Generation of target code from the three-address code of the source program	6

Lab – XV: Machine Learning Laboratory (CS4172)

Assignment/ Sl. No.	Module Name and Topics	No. of lab hours

1	Implement a Classifier to predict diseases with two class labels. Performance evaluation based on different classifiers using 5-fold cross validation technique and comparison.	4
2	Use Support Vector Machine (SVM) for multiclass classification. Analyze the overfitting and underfitting problem.	6
3	Use fully connected neural network to train a network on MNIST dataset and predict the accuracy. Run the network by changing different hyper-parameters.	6
4	Train a Convolution neural network with max pooling and a fully connected layer at the top, to classify the flower images. Plot the graph for loss vs epoch and accuracy (train, test set) vs epoch by changing the hyper parameters.	8
5	(a) Train an LSTM model with FC layer applied in the final layer for sentiment analysis using the following techniques: embedding, AdamOptimizer, LSTM and different activation functions. (b) For the same run a GRU model, a bidirectional model.	16

8th Semester

Core Theory – XXII: Artificial Intelligence (CS4201)

Module / Sl. No.	Module Name and Topics	No. of Lectures
	Introduction	
1	Overview of Artificial Intelligence (AI).	1
	Problem Solving and Game Playing	
2	Problem Representations: Problem Representation in State Space, Production System – Components, Advantages, Applications.	2
3	Uninformed Searches: BFS, DFS, Iterative Deepening (ID) Search with Space and Time Complexities.	3
4	Informed Searches: Heuristic Functions, Hill Climbing Search, Best First Search, A* Algorithm, Admissibility of A* Algorithm, IDA* Algorithm, Problem Reduction and AO* Algorithm, Means-Ends Analysis.	5
5	Adversarial Search: Games, Evaluation Function, The Min-Max Algorithm, Alpha-Beta Pruning.	1
	Logic and Reasoning	
6	Introduction: Formal Logic, Entailment, Proofs, Soundness and Completeness, History of Logic and Knowledge – The Last Millennium, Logic in Ancient Greece, Logic in Ancient India.	1
7	Proposition and Predicate Logic: Automated Reasoning using Resolution-Refutation in Propositional Logic (PL), Resolution Algorithm, Skolem Standard Form in First Order Predicate Logic (FOPL), Clausal Form, Unification and Substitution, Unification Algorithm, Theorem Proving with Resolution-Refutation in FOPL, Answer Extraction, Various Resolution Strategies.	6
8	Introduction to Modal Logic: Syntax and Semantics, Kripke Structures, Truth of Modal Formulas, Truth of Modal Formulas, Inference Rules, Axioms and their Corresponding Properties, Selected Applications like Modal Logic and Game Trees.	3

9	Introduction to Temporal Logic: Linear Time Temporal Logic, Brunch Time Temporal Logic, Concurrency.	3
10	Nonmonotonic Reasoning: The Closed-World Assumption, Predicate Completion, Taxonomic Hierarchies and Default Reasoning, Circumscription, Default Theories.	3
11	Reasoning with Uncertainty: Review of Probability Theory, Using Bayes' Rule in Uncertain Reasoning, Propagating Probabilistic Inferences, Belief Networks, Combining Evidences to form Beliefs, The Dempster-Shafer Theory.	3
	Logic Programming	
12	Horn Clause and Basic Inferencing with them, PROLOG as a Restricted Resolution-Based Theorem Prover, Control Strategy of PROLOG, List Manipulations, Accumulators, The System Predicate 'CUT', Negation as Failure, Implementations of Sorting Algorithms in PROLOG, Tree Representations and Operations in PROLOG, Representation of Graphs and Problems on Graphs in PROLOG, Solving AI Problems in PROLOG.	8
	Expert Systems	
13	Rule Based Expert System: Rules as Knowledge Representation Technique, Architecture of Rule Based Expert System, Example, Forward Chaining and Backward Chaining, Advantages and Disadvantages, Uncertainty Management in Rule Based Expert Systems, Certainty Factors Theory, Comparisons of Baysian Reasoning and Certainty Factors.	2
14	Frame Based Expert System: Frames as Knowledge Representation Technique, Inheritance in Frame Based System, Methods and Demons, Interaction of Frames and Rules.	2
	Planning	
15	Planning with Certainty: Representing States, Actions and Goals – Explicit State-Space Representation, The STRIPS Representation, Feature-Based Representation of Actions; Forward Planning, Regression Planning, Planning as a Constraint Satisfaction Problem, Partial-Order Planning.	4
16	Planning with Uncertainty: Preferences and Utility – Axioms for Rationality, Factored Utility, Prospect Theory; Single Stage Decision Network, Sequential Decisions – Decision Networks, Policies, Variable Elimination for Decision Networks; The value of Information and Control, Decision Processes – Policies, Value Iteration, Policy Iteration, Dynamic Decision Network, Partially Observable Decision Processes.	6

Books (Text and References – Includes Books for Associated Laboratory Course):

1) Artificial Intelligence-A Modern Approach, Stuart Russel and Peter Norvig, 3rd Ed., Pearson,2014.
2) Artificial Intelligence - Foundations of Computational Agents, David L. Poole and Alan Mackworth, 2nd Edition, Cambridge University Press, 2017.
3) A First Course in Artificial Intelligence, Deepak Khemani, McGraw Hill Education, 2013.
4) Artificial Intelligence, Elaine Rich, Kevin Night and Shivshankar B. Nair McGraw Hill Education, 2017.
5) Artificial Intelligence - A Guide to Intelligent Systems, Michael Negenvitsky, 2nd Edition, Pearson, 2008.

6) Artificial Intelligence, Structure, Strategies for Complex Problem Solving, George F. Luger, 5th Edition, Pearson, 2008.
7) Prolog Programming for Artificial Intelligence, Ivan Bratko, 3rd Edition, Pearson, 2002.
8) Techniques of Prolog Programming, with Implementation of Logical Negation and Quantified Goal, T. Van Lee, Wiley, 1992.
9) Programming in Prolog, William F. Clocksin and Christopher S. Melish 5th Edition, Springer, 2003.
10) Prolog Programming in Depth, Michael A. Covington, Donald Nute and Andre Vellino, Prentice Hall, 1997.

Core Elective – II: Departmental Elective – IV

Departmental Elective – IV: Big Data Analytics (CS4221)

Module No.	Topics	Hours
1	Introduction To Big Data Introduction, Challenges in Big Data, Big data applications, Non - Linear Data Structures for Big Data.	3
2	MapReduce Architecture Apache Hadoop Environment, Basic of YARN. Moving Data in and out of Hadoop, Understanding inputs and outputs of MapReduce framework, Data Serialization, Hadoop Architecture, Hadoop Storage: HDFS Interface, Concept of Namenode and Datanode, Map and Reduce tasks, Job Scheduling.	6
3	Big Data & Machine Learning Overview of machine learning; Introduction to machine learning tools for Big data - Spark & SparkML, H2O, Azure ML	6
4	Big data Processing & Storing Streaming Data Data flow, Data Ingest with Flume and Scoop and Hadoop archives, Handling Heterogeneous data with NoSQL, Exploring Column Based NoSQL Database: HBase, Distributed Stream Data Processing. Apache Spark Streaming, NoSQL Data Architecture pattern, Visualization of BIG Data.	8
5	Big Data & Cloud Computing Big data management in cloud, parallel database architectures: Google File System (GFS), Cloud-based parallel programming framework: Parallel programming with Message Passing. Different Service Models in Cloud Computing: SaaS, PaaS, IaaS. Big data processing in Cloud Computing environments.	8
6	Social Network Analysis Cascading Behaviour in Networks: Diffusion in Networks, Modelling Diffusion - Cascades and Cluster, Social Network graphs Clustering, Page Rank, Betweenness, closeness, degree centrality of Graph, community detection, Network Modularity, Recommender systems.	6
7	Big Data Privacy, Ethics And Security Maintaining Data Integrity in Big Data Platforms, Access Policies in Big Data Platforms, Necessity of Big Data Privacy – Ethics, Ownership, Ethical Guidelines, Big Data Security in Organization.	3

Reference Books : 1. "Analytics in a Big Data world: The essential Guide to Data science and its applications Bart Baesen, Wiley, 2014
2. "Big Data:Principles and Best Practices of scalable Real-Time Data Systems". Nathan Marz and James, Manning Publications, 2015
3. "Big Data Analytics" , Seema Acharya and Subhasini Chellappan, Wiley 2015
4. Big Data Analytics- Introduction to Hadoop, Spark, and Machine-Learning Raj Kamal and Preeti Saxena, McGraw-Hill Education, 2019

Departmental Elective – IV: Computer Control and Industrial Processes (CS4222)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	Introduction to modern control theory	2
2	State-Space system modelling methods in continuous domain	3
3	Sampler and Hold transfer function	2
4	Discrete dynamical system representation	3
5	Z-transform and approximations	4
6	Concept of stability, Controllability and Observability criterion	6
7	Controller and observer design	4
8	Concepts of estimation, prediction and smoothing	4
9	Introductory ideas of optimal, adaptive and stochastic control	4
10	Implementation of control system in industry	4
	Total	36

Departmental Elective – IV: Computational Complexity (CS4223)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction; P and NP** Review of Turing machines, universal Turing machines, and uncomputable functions.	3
2	**P, NP, coNP, and NP-Completeness** P vs. NP; NP vs. coNP; and NP-completeness.	3
3	**More on NP and NP-Completeness** NP-completeness of SAT and other problems. Search vs. decision and self-reducibility.	3
4	**Diagonalization** Time/space hierarchy theorems. Ladner's theorem. Relativization of the P vs. NP question.	3
5	**Space complexity** PSPACE and PSPACE-completeness; NL and NL-completeness. Savitch's theorem; the Immerman-Szelepcsenyi theorem.	3
6	**The polynomial hierarchy** The polynomial hierarchy. Time-space tradeoffs for SAT. **non-uniform complexity** PH in terms of oracle machines. Introduction to non-uniform complexity. Circuit complexity and P/poly. The Karp-Lipton theorem. Logarithmic-depth circuits.	3
7	**Randomized computation:** RP, BPP, ZPP. Error reduction. Probabilistic algorithms. Relation of BPP to the polynomial hierarchy and non-uniform computation. BPP-completeness and promise problems. Randomized space complexity	3
8	**Interactive proofs** Interactive proofs, MA, and AM. Graph non-isomorphism in AM. An interactive proof for coNP, IP=PSPACE. Introduction to zero-knowledge proofs.	4
9	**Zero-knowledge proofs** Honest-verifier and dishonest-verifier perfect zero-knowledge proofs.	4

	Computational zero-knowledge proofs; perfect zero-knowledge arguments.	
10	**The PCP theorem** The PCP theorem and applications to proving inapproximability. A proof that NP is in PCP.	4
11	**The complexity of counting** Hardness of unique-SAT. Approximating #P with an NP oracle. Toda's theorem.	3

Departmental Elective – IV: Algorithmic Game Theory (CS4224)

Module/ Sl. No.	Module Name and Topics	No. of Lectures
1	Introduction, Centralized versus Decentralized Games, Strategies and equlibria- Nash equilibrium, Correlated equilibrium	4
2	Introduction to Linear Programming, Simplex Method, Duality.	4
3	Maxmin and Minmax Strategies, Two -player zero sum games, linear programming formulation.	2
4	Game Dynamics: Weighted Majority Algorithm, Bandit Algorithm, Converging to Nash equilibrium in zero sum games, Lemke-Howson algorithm to solve two player general sum games, converging to correlated equilibrium in general sum games, Best Response Dynamics and Potential Games, NP-completeness results related to finding Nash equilibrium.	8
5	Price of anarchy and price of stability: Definition, Routing games, hoteling games.	3
	Mechanism design	
6	Mechanism Design Basics, Myerson's Lemma, Algorithmic Mechanism Design, Stable Matching and Deferred Acceptance Algorithm. Walrassan Equilibrium for Agents with Gross Substitute Valuations.	6
7	Auction Basics: 1st Price Auction, The Vickrey Auction (2nd Price Auction), The Groves Mechanism and the VCG Auction to Maximize Social Welfare, Truthfulness of Dominant Strategy, Beyond Social Welfare- Monotone Mechanism in Single Parameter Domains. Case Study- Spectrum Auction.	6
8	Auction and Approximation Algorithms: Truthfulness via Monotonicity, Knapsack Auctions.	3
9	Revenue Maximization: Profit Extractors, Random Sampling Auctions, Online Digital Goods Auctions.	4
	Total	40

Reference Books:

1) Algorithmic Game Theory, Noam Nisan and Tim Roughgarden, Cambridge University Press, 2007
2) Multiagent Systems, Algorithmic, Game-Theoretic and Logical Foundations, Yoav Soham and Kevin Leyton-Brown, Cambridge University Press, 2009
3) Game Theory and Mechanism Design, Y. Narahari, IISc Press and World Scientific, 2014

Departmental Elective – IV: Reconfigurable Computing (CS4225)

Module/ Sl. No.	Module Name and Topics	No. of Lectures
1	**Device Architecture:** General Purpose Computing Vs Reconfigurable Computing, Simple Programmable Logic Devices (SPLD), Complex Programmable Logic Devices	8

	(CPLD), FPGAs Device Architecture, Fine-grained architectures, Coarse-grained architectures	
2	**Reconfigurable Platforms Design Cycle:** The Design Flow, Technology Mapping, FPGA Placement and Routing, Configuration Bitstream Generation, Case Studies with Appropriate Tools.	8
3	**Design methodology and techniques:** Top-down, modular design, Controller/controlled-component architecture, Implementation methods - traditional, MUX, ROM, Design and Implementation techniques using FPGA's	8
4	**Register Transfer (RT)/Logic Synthesis:** Controller/Datapath synthesis, Logic minimization	6
5	**Advanced Topics:** Partial Reconfiguration, Dynamic Reconfiguration, Fault Tolerance	6

Reference Books:

1. Christophe Bobda, "Introduction to Reconfigurable Computing – Architectures, Algorithms and Applications", Springer.
2. C. Maxfield, "The Design Warrior's Guide to FPGAs", Newnes.
3. Scott Hauck and Andre Dehon (Eds.), "Reconfigurable Computing – The Theory and Practice of FPGA Based Computation", Elsevier / Morgan Kaufmann.

Departmental Elective – IV: Quantum Computing (CS4226)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Introduction:** Introducing quantum mechanics. Quantum kinematics, quantum dynamics, quantum measurements. Single qubit, multiqubits, gates. Density operators, pure and mixed states, quantum operations, environmental effect, decoherence. Quantum no-cloning, quantum teleportation.	5
2	Quantum Gates, Quantum circuits, Universal gates, quantum parallelism, Deutsch-Josza algorithm.	3
3	**Quantum Entanglement:** Quantum correlations, Bell's inequalities, EPR paradox. Theory of quantum entanglement. Entanglement of pure bipartite states. Entanglement of mixed states. Peres partial transpose criterion. NPT and PPT states, bound entanglement, entanglement witnesses.	8
4	**Quantum Algorithm:** Introduction to quantum algorithms. Deutsch-Jozsa algorithm, Grover's quantum search algorithm, Simon's algorithm. Shor's quantum factorization algorithm.	10
5	**Quantum Error Correction:** Errors and correction for errors. Simple examples of error correcting codes in classical computation. Linear codes. Shor code, Theory of Quantum Error – Correction, Constructing Quantum Codes, Stabilizer codes, Fault – Tolerant Quantum Computation, Entropy and information – Shannon Entropy, Basic properties of Entropy, Von Neumann, Strong Sub Additivity, Data Compression, Entanglement as a physical resource.	6
6	**Quantum Cryptography:** Cryptography, classical cryptography, introduction to quantum cryptography. BB84, B92 protocols. Introduction to security proofs for these protocols.	4

7	**Implementations:** Different implementations of quantum computers. NMR and ensemble quantum computing, Ion trap implementations. Optical implementations.	4

Open Elective – II: CS

Open Elective – II: Data Mining (CS4261)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Overview:** Knowledge Discovery in Database – Necessity and challenges in data mining, Architecture of a typical data mining system, Classification of data mining system, Overview of data mining steps and techniques.	2
2	**Data preprocessing and representation:** Types of data, data cleaning, transformation, reduction, missing values, Discretization and Concept hierarchies, Measures of similarity and dissimilarity among data	3
3	**Association Analysis:** Association Rules, Apriori Principle, Rule Generation in Apriori Algorithm, FP- Growth Algorithm, Evaluation of Association Patterns.	3
4	**Classification Analysis** Classification Algorithms - Decision Tree Induction, Rule Based Classifier, Nearest Neighbour Classifier, Bayesian Classifier, Support vector machines. Artificial neural networks, Estimating classifier accuracy (holdout, cross-validation, leave-one-out).	8
5	**Cluster Analysis** Clustering Algorithms - Partition based Clustering, Hierarchical clustering, Density based Clustering, Graph-based clustering. Cluster Evaluation and Optimization - Intra and inter cluster distance, Validity index (like Dunn's index, DB index, CS index etc.), Cluster splitting and merging, Validity index based and Stability factor based cluster optimization.	8
6	**Advanced techniques, Data Mining software and applications** Text Mining - Keyword based search and Mining, Text Analysis and Retrieval, Mathematical Modelling of Documents, Similarity based matching for documents, Latent Semantic Analysis. Web mining - classifying web pages, extracting knowledge from the web Case Studies with Data Mining Tools.	10

Open Elective – II: Soft Computing (CS4262)

Module / Sl. No.	Module Name and Topics	No. of Lectures
1	**Overview:** Goal of the subject, Definition of soft computing, How it differs from hard computing, Components of soft computing.	1
2	**Fuzzy Sets and Systems:** Overview of Classical Crisp Sets, Crisp set versus Fuzzy set, Membership functions, Fuzzy rule generation, Operations on fuzzy sets, Properties of fuzzy sets, Fuzzy Relations, Fuzzy Measures, Fuzzy Arithmetic, Composition operations, Fuzzy Numbers, Linguistic Variables, Arithmetic Operations on Intervals & Numbers, Lattice of Fuzzy Numbers, Fuzzy Equations, Fuzzy extension principle, Approximate Reasoning, Fuzzy implication functions, Fuzzy Inference Systems, Type-2 fuzzy sets, Applications, Fuzzy Logic versus Classical Logic	10

3	**Artificial Neural Networks:** History, overview of biological Neuro-system, Definition and Properties of Artificial Neural Network (ANN), Applications of Artificial Neural Networks, Mc-Pitts Model, ANN architecture, Learning Paradigms-Supervised, Unsupervised and reinforcement Learning, Hebbian learning, Perceptions learning rule, Delta learning, Back Propagation Algorithm, Multilayer Perceptron Model, Competitive learning networks, Kohonen self organizing networks, Hopfield Networks, Associative Memories, The boltzman machine: Working principles and Applications, Radial Basis function network, Recurrent neural network, current topics: Deep Learning, Applications.	10
4	**Optimization methods:** **Genetic Algorithms -** Basic concepts of genetic algorithms, Traditional search method vs. Genetic Algorithm, How it works and where applicable, Encoding, Fitness function, Selecting, crossover, mutation, schema analysis, analysis of selection algorithms; convergence, genetic modeling, Applications, problem solving: Graph coloring, TSP,etc. **Particle Swarm Optimization -** Basic Concepts, Local Best, Global Best, Velocity Updation, Position Updation, Variant of PSO, Applications. **Differential Evaluation -** Basic Concept, Initialization of vectors, Target Vector, Donor Vector, Selection, Mutation, Crossover, Control Parameters, Applications **Other Soft Computing Approaches -** Simulated Annealing, Ant colony optimization, Tabu Search, Firefly Algorithm, Cuckoo Search Algorithm, etc.	12
6	**Overview on Hybrid Systems:** Integration of Artificial neural networks, Fuzzy logic, and Evolutionary Algorithms, Applications	3

Books:

1. "Fuzzy Sets & Fuzzy Logic", G. J. Klir & B. Yuan, *PHI.*
2. "Neural Networks: a comprehensive foundation", Haykin, *Pearson.*
3. "Neuro-fuzzy Systems", Chin-teng-lin, C.S. Lee.
4. "Genetic Algorithms", David E. Goldberg, *Pearson.*
5. "Principles of Soft Computing", S. N. Sivanandam, S. N. Deepa, *Wiley-India.*

Core Lab – XVIII: Artificial Intelligence Laboratory (CS4271)

Module /Sl No.	Module Name and Topics	No. of Hours
1	Prolog Programs Based on List Manipulation	3
2	Prolog Programs Based on Arithmetic Operation, Implementation of Sets, Cut Predicates etc.	3
3	Prolog Programs to Implement different Sorting Algorithms	3
4	Prolog Programs to Implement and Manipulate Binary Tree, Binary Search Tree .	3
5	Prolog Programs for Implementation of Graph and related problems..	3
6	Prolog Programs to Implement 8-Queen Problem & Knight's Tour.	3
7	Prolog Programs for Implementation of Production System Models like Monkey Banana Problem, Missionaries and Cannibals Problem and Misc. Problems like Tower of Hanoi, Next Higher Permutation, Realizations of Relational and Arithmetic Operations with only a symbol and a successor	6

	function etc.	
8	Program to Implement Automated Theorem Prover in Propositional Logic	3
9	Programs to Implement & Compare Search Algorithms like BFS, DFS, ID, Hill Climbing, Best First, A* Algorithm on AI Problems like 8-Puzzle.	6
10	Program for Mini-Max Search with alpha-beta Prunning on Problems like Tic-tac-toe.	3