Indian Institute of Engineering Science and Technology, Shibpur

Department of Computer Science and Technology

M. Tech. (CST) Syllabus

First Semester

Paper - I (Departmental Core) – *Group A (Any one from the Group)*

Advanced Algorithms (CS 5101)

Sl. No.	Topics	No. of Lectures
1	**Design Paradigms: Overview:** Divide and conquer, Dynamic Programming, Greedy Algorithms, Graph search and traversal techniques, Backtracking, Branch and Bound.	4
2	**Network Flow, Matrix Operations** Network flow – Augmenting paths, Ford-Fulkerson method, Maximum bipartite matching Matrix Operations – Strassen's algorithm, Solving system of linear equations, Inverting matrices	5
3	**String Matching Problem** Introduction to string-matching problem, Naïve algorithm, Rabin Karp, Knuth Morris Pratt, BoyerMoore algorithms and complexity analysis.	5
4	**Computational Geometry:** Line-segment properties, Sweep algorithms, Finding convex hull	4
5	**NP – Completeness, Approximation Algorithms:** Theory of NP- Hard and NP-Complete Problems: P, NP and NP-Complete complexity classes; A few NP-Completeness proofs; Other complexity classes. Approximation Algorithms: Performance bounds (ratio bound, relative error bound) of the problems, Approximation scheme, A few Approximation Algorithms.	8
6	**Probabilistic Algorithms & Randomized Algorithms:** Numerical probabilistic algorithms, Las Vegas and Monte Carlo algorithms, Game-theoretic techniques, Applications on graph problems	6
7	**Parallel Algorithms:** Introduction, Models, speedup and efficiency, Some basic techniques, Examples from graph theory, sorting, Parallel sorting networks. Parallel algorithms and their parallel time and processors complexity.	8

References:

1. Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein
2. Advanced Data Structures by Peter Brass
3. Randomized Algorithms by Rajeev Motwani and Prabhaker Raghavan
4. Parallel Algorithms by H Casanova, A Legrand, Y Robert

Principles of Programming Languages (CS 5102)

Sl. No.	Topics	No. of Lectures
1	Idea of computation through Lambda Calculus, Grammars, Automata, and Recursive Functions	6
2	Syntax and Formal Semantics (static and dynamic) of programming languages	8
3	Language Processing (Eg., Interpreter, Compiler, etc.) based on syntax and semantics	6
4	Functional Programming, Imperative Programming, and Object Oriented Programming – Price and Benefit	
5	Building Abstraction with Procedures and Data	6
6	Modularity, Objects, and State	6
7	Metalinguistic Abstraction	4
8	Concurrency Modeling	4
9	Programming Language Evaluation Criteria	3

References /Books:

1. Structure and Interpretation of Computer Programs by Harold Abelson and Gerald Jay Sussman with Julie Sussman, The MIT Press
2. Semantics of Programming Languages by R. D. Tennent
3. Concepts of Programming Languages by Robert W. Sebesta

Paper - II (Departmental Core) – *Group B (Any one from the Group)*

Logics for Computer Science (CS 5105)

Module / Sl No	Module Name and topics	No. of Lectures
1	**Proof:** What is a Proof? Proof Methods.	2
2	**Propositional Logic:** Syntax and Semantics of Propositional Logic. Tautologies and Axiom Systems. Proof of Soundness and Completeness.	5
3	**First Order Predicate Logic and PROLOG:** Basic concepts about Syntax and Semantics of Predicate Calculus. Converting Natural Language into FOPL wffs. Structures, Models, Satisfation and Validity. Skolem Theorem Herbrand's Theorem, Resolution Principles and Unification with Applications to Automated Theorem Proving. Soundness and Completeness of Resolution, Various Resolution Strategies. Horn Clause and Basic Inferencing with them, PROLOG as a Restricted Resolution-Based Theorem Prover. PROLOG Control Strategy, List Manipulation, Accumulators, The System Predicate 'CUT', CUT and Fail Combination, 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 A.I. Problems using PROLOG.	10 8

4	**Natural Deduction Systems:** Goal, Proofs, Examples.	4
5	**Introduction to Modal Logic:** Syntax and Semantics, Kripke Structures, The Landscape of Modal Logic, Frame Correspondence, Selected Applications like Modal Logic and Games.	5
6	**Introduction to Temporal Logic:** Linear- time Temporal Logic, Branching-time Temporal Logic, Concurrency.	5

References:

1. Arindama Singh, Logics for Computer Science, Prentice Hall of India.
2. C. L. Chang and R. C. T. Lee, Symbolic Logic and Mechanical Theorem Proving, Academic Press.
3. M. Ben-Ari, Mathematical Logic for Computer Science, Springer.
4. E. Mendelson, Introduction to Mathematical Logic, Chapman and Hall.
5. Johan Van Benthem, Modal Logic for Open Minds, CSLI Publications.
6. Zohar Manna and Amir Pnueli, The Temporal Logic of Reactive and Concurrent Systems, Springer Verlag.
7. William F. Clocksin and Christopher S. Melish, Programming in Prolog, Springer.
8. Ivan Bratko, Prolog Programming for Artificial Intelligence, Addison Wesley.

Mathematics for Computer Science (CS 5106)

Sl. No.	Topics	No. of Lectures
1	Review of Sets, relations, Lattice, chains, topological sort, Mathematical Induction, Infinite sets, Counting, pigeonhole principle, Asymptotic notation, asymptotic equivalence, solving recurrence	8
2	Probability theory and applications	6
3	Linear Algebra: Fields, Vectors spaces, subspaces, Linear independence, dependence and dimension, Linear transformations. Matrices and determinants. Properties of matrices and determinants. Systems of linear equations. Eigen values, eigenvectors, eigenspaces, diagonalization and the spectral theorem. Factorization and singular value decomposition.	10
4	Logic: proof and proof methods, Propositional logic, First order logic (FoL), Converting natural language into FoL wffs, Structures, models, satisfaction and validity, Axiomatization, soundness and completeness. Refutation and logic programming.	8
5	Numerical methods - Numerical solution of nonlinear equations, Interpolation and polynomial approximation, Numerical integration and differentiation, Numerical linear algebra	8

References:

1. Kenneth Rosen, Discrete mathematics and its applications.
2. Chung Liu, Introduction to combinatorial mathematics.
3. Eric Lehman, Tom Leighton, and Albert Meyer, Mathematics for Computer Science
4. Numerical methods for scientists and Engineers by Richard W. Hamming

Paper - III (Departmental Core) – *Group C (Any one from the Group)*

Advanced Computer Architecture (CS 5109)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction** Development of computer systems, von Neumann machine, performance measure, CISC and RISC processors	3
2	**Memory** Virtual memory system; cache – properties, mapping, performance; CAM; mass storage - RAID	3
3	**Processor design** Pipelining – instruction and arithmetic pipeline; linear pipeline processors – asynchronous and synchronous models; non-linear pipeline processors - reservation table, latency analysis, collision free scheduling, scheduling optimization; superpipelined design Pipeline hazards - structural, data and control hazards, role of reservation table, minimizing data hazard stalls, data forwarding, dynamic scheduling, reducing pipeline branch penalties - branch-delay slot, prediction schemes, branch predictors; exceptions handling - in-order/ out-of-order issues	12
4	**Cache design** Cache updates – write-back and write-through caches; reducing compulsory, capacity and conflict misses, miss penalty and hit time reduction; cache coherence - data consistency, enforcing cache coherence, directory based protocol, snooping, MESI and other cache models	10
5	**Instruction-level parallelism** Multiple issue processors; superscalar processor – structure, pipeline scheduling; VLIW; compiler support for exploiting ILP	4
6	**Parallel computers** Flynn's taxonomy - SISD, SIMD – shared memory, interconnection network; MISD and MIMD machines Parallel and scalable architectures; multiprocessor system interconnects – shared bus, multi-port, crossbar, multistage networks; vector processors; distributed shared-memory architectures; Cluster Computer Architecture Program flow mechanisms; dataflow processors; threaded dataflow; hybrid structures	8

References:

1. John Paul Shen and Mikko H. Lipasti, Modern Processor Design: Fundamentals of Superscalar Processors, Tata McGraw-Hill.
2. John L. Hennessy and David A. Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufmann.
3. M. J. Flynn, Computer Architecture: Pipelined and Parallel Processor Design, Narosa Publishing House.
4. Kai Hwang, Advanced Computer Architecture: Parallelism, Scalability, Programmability, McGraw-Hill.
5. Parallel Computation: Models and Methods by Selim G. Akl; Pearson

High Performance Computing (CS 5110)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Parallel Processing Concepts; Levels and model of parallelism: instruction, transaction, task, thread, memory, function, data flow models, data and demand-driven computation	5
2	Pipelining - hazards Instruction-level parallelism, superscalar, super-pipelined and VLIW architectures Array processors, Vector processors, Vectorisation methods, System interconnects, cache coherence, Centralized and distributed shared-memory architectures	14
3	Design issues in HPC: Load balancing, scheduling, synchronization and resource management; Operating systems for scalable HPC	5
4	Scalable storage systems: RAID, SSD cache, SAS, SAN HPC based on cluster, cloud, and grid computing	6
5	Accelerated HPC: architecture, GPU, FPGA, Xeon Phi, Cell BE programming, Power-aware HPC Design Beta scale computing; big data processing, optics in HPC, quantum computers.	10

References:

1. Georg Hager and Gerhard Wellein. Introduction to High Performance Computing for Scientists and Engineers (1st ed.). CRC Press, Chapman & Hall/CRC Computational Science, India
2. Vipin Kumar , Ananth Grama , Anshul Gupta , George Karypis. Introduction to Parallel Computing (2nd ed.). Pearson India .
3. John L. Hennessy and David A. Patterson. Computer Architecture: A Quantitative Approach (5th ed.). Elsevier India Pvt. Ltd.
4. David B. Kirk and Wen-mei W. Hwu. Programming Massively Parallel Processors: A Hands-On Approach (1st ed.). Elsevier India Pvt. Ltd.

Paper - IV (Departmental Elective)

Machine Learning (CS 5121)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Overview:** Motivation, probability and statistics, linear algebra, Linear Regression	3
2	**Supervised Learning:** generative/discriminative learning, parametric/nonparametric learning, Perceptron neural models, gradient descent, Backpropagation, validation, test data, overfitting, Regularization, Naive Bayes Model, Logistic regression, Decision Trees, and support vector machines	10
3	**Unsupervised Learning:** clustering, Kohonen Network, SOFM, dimensionality reduction, kernel methods; Advanced discussion on clustering and Gaussian Mixture Models, Expectation Maximization	8
4	**Optimization Techniques**	4
6	**Reinforcement learning**	3

7	**Deep Learning Architecture:** CNN, RNN, GAN, Autoencoder	9
8	**Ensemble methods**	3

References /Books:

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

Information and Coding theory (CS 5122)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Revision of probability theory:** Bayesian theorem, conditional probability, joint probability, expectation and variance of random variables.	2
2	**Concept of Information:** Zero memory source, Markov source, extensions of information source, source coding, channel coding, uncertainty, information entropy	3
3	**Source coding:** Shannon's first theorem, Shannon Fano coding scheme, Huffman coding scheme, Data compression, Kraft McMillan inequality	3
4	**Channel coding**: Channel coding theorem, error at receiver, channel equivocation, mutual information, cascading of channels, Differential entropy, channel capacity theorem, Shannon Limit	4
5	Message transmission: Concept of message rate, reliable transmission of information over an unreliable channel, Shannon–Hartley theorem	4
6	**Introduction to algebraic coding theory:** Groups, fields, GF(p^m), vector space, matrices, representation of message and code in vector and polynomial form	3
7	**Error Control coding:** Linear block codes, concept of generator matrix, parity check matrix, error correction techniques, syndrome based decoding, standard array based decoding	4
8	**Cyclic codes:** Definition, generator polynomial, parity check polynomial, systematic form, random error correction, burst error correction, multiple error correcting cyclic codes, generalized BCH codes, design distance	4
9	Ideas of non-binary codes, Convolutional codes, LDPC codes	5
10	Applications of coding theory in data security and cryptography	4

References/Books:

1. Lin and Costello, Error control Coding
2. Moon, Error correction coding
3. Hamming, Coding and Information theory
4. Cover and Thomas, Elements of information theory

VLSI System Design (CS 5123)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Introduction to VLSI System Design: MOS Devices, Circuits and Fabrication, Design Principles and Characteristics of MOS Devices in Logic Circuits, Size and Complexity of Integrated Circuits, Feature Size, Impact of Shrinking, Clocking, Scaling, PLA Minimization and Folding, Inverters and Logic Gates, Design Rules and Layouts, Stick Diagram, Transistor Sizing, CMOS Downscaling, Process Technology, Nanotechnology Devices, VLSI / ULSI.	3
2	ASIC: Introduction, Advantages, Examples, Classification, VLSI Design style and Design Flow, Economics of ASIC.	2
3	Simulation: Types of Simulation, Logic Simulation, Circuit Simulation, Gate level Simulation, Switch Simulation.	2
4	VLSI Design Process: System Specification, Functional Design, Logic Design, Circuit Design, Physical Design, Verification, Fabrication and Packaging.	2
	Design Styles: Custom Design, Standard-Cell Design, Gate-Array Design, FPGA (Architecture and Physical Design) and MCMs.	2
5	Physical Design Issues: Partitioning – Iterative and Constructive Algorithms. Floorplanning – Rectangular Dual and Hierarchical Method. Placement – Force-directed, Simulated Annealing and Genetic Algorithms. Routing – Area Routing, Channel Routing, Switchbox Routing, Performance driven Placement and Routing, Clock Routing. Layout Compaction. Design Rule Verification and Complexity Issues.	7
6	VHDL: Introduction, Composite Data Type, Processes, Subprograms, Behavioral & Structural VHDL, Packages, Libraries, VHDL in Simulation – Test Bench, VHDL for Combinational, Sequential logic & FMS.	5
7	Case Studies: Arithmetic Logic Unit, Digital Filter VHDL for testing.	2
8	Idea of System Level Design using VHDL / Verilog / MATLAB, System and FPGA Synthesis of the systems.	3
9	Logic Synthesis: Design Methodology, PLA Based synthesis, Two and Multilevel combinational circuit – OBDD, Synthesis, Delay, Testability.	2
10	SOC Design: ASIC and SOC, IP-Reuse & Integration, Design Factors, Design Flow, Verification, Low Power Design – Algorithm, Architecture, Optimization.	3
11	Application: DSP and Audio-Video Processor.	2
12	Design for Testability: Fault Types and Models, Ad Hoc Testable Design Techniques, Scan –based Techniques, Built-In Self Test Techniques	2

Refernces:

1. An Introduction to Physical Design – Surrafzadeh, Wong, TMH Inc.
2. Algorithms for VLSI Physical Design Automation – Naveed Sherwani – Kellwer Academic Publisher.
3. Application Specific Integrated Circuit – by Sebastian Smith – Pearson Education Asia.
4. VHDL & FPLD in Digital System Design – by Salcic Zoran – Kellwar Academic Publisher.
5. Logic Synthesis – S. Devadas, A. Ghosh, K. Kellwar, McGrawHill Inc.

6. Logic Design Theory – N. N. Biswas, PHI.
7. FPGA Architecture and CAD tools – by V. Metz & J. Rose, Addison Weseley.
8. Reuse Methodology Manual for System on Chip Designs – Kellwar Academic Publishers.
9. Surviving the SOC Revolution – A Guide to Platform based Design – H. Chang, L. Cooke, M. Hunt, G. Martin, A. McNelly and L. Todd, Norwell, MA: Kellwar Academic Publisher.

Digital Signal Processing (CS 5124)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction:** Review of discrete-time signal and system analysis; Advantages and typical applications of DSP	2
2	**Sampling and Quantization:** Sampling and discrete-time processing of continuous time signals, Sampling of low-pass and band-pass signals; Uniform and non-uniform quantization, Lloyd-Max algorithm, Log-companding, A-law, μ-law; Adaptive quantization and prediction	6
3	**Orthogonal transforms:** Properties and applications of DFT, implementing linear time invariant systems using DFT, circular convolution, linear convolution using DFT; Fast Fourier Transform, FFT algorithms: Decimation in time, decimation in frequency; Goertzel algorithm; Application of transform in speech, audio, image and video coding, Karhunen-Loeve Transform, DCT, JPEG and MPEG coding standards	12
4	**Digital Filter design techniques:** IIR and FIR filters, filter design specifications; Design of digital IIR filters: Impulse invariant, and bilinear transformation techniques for Butterworth and Chebyshev filters; **Design of FIR filters:** Windowing, frequency sampling filter design, optimum approximations of FIR filters	8
5	**Multi-rate Signal Processing:** Fundamentals of multirate systems, Decimation and interpolation, application of Multirate DSP in sampling rate conversion; Filter banks; Polyphase structures; Quadrature-mirror filter bank; Wavelet transform and its relation to multi-ratefilter banks; applications to speech and audio coding.	10
6	**Basic concept of Adaptive Digital Signal Processing:** Adaptive Wiener filter and LMS algorithm; Applications of adaptive filtering to echo cancellation and equalization	4

***References**:*

1. Proakis, J.G. and Manolakis, D.G., "Digital Signal Processing: Principles, Algorithm and Applications", 4th Ed., Pearson Education.
2. Ifeachor, E.C. and Jervis, B.W., "Digital Signal Processing: A Practical Approach", 2nd Ed., Pearson Education.

3. Mitra, S.K., "Digital Signal Processing-A Computer Based Appraoach", 3rd Ed., Tata McGraw-Hil
4. Oppenheim, A.V. and Schafer, R.W. with Buck, J.R., "Discrete TimeSignal Processing", 2nd Ed., Prentice-Hall of India.

Cognitive Science (CS 5125)

Sl. No.	Topics	No. of Lectures
1	Origin and History of Cognitive Science, Essential Characteristics and Long-term Goals of Research in the Cognitive Science Especially in context of Cognitive Psychology and Artificial Intelligence.	2
2	Computational Models of Intelligence. Essential Features of Computational Models.	1
3	Knowledge Representations: Semantic Nets, Frames, Scripts.	2
4	Introduction to Neural Networks: Perceptrons and the LMS Algorithms, Backpropagation, Multi-Layer Perceptrons, the Neural Viewpoint.	3
5	Training Neural Networks: Activation Functions, Initialization, Drop Out, Batch Normalization, Updating Rules, Data Augmentation, Transfer Learning.	3
6	Competitive Learning and Kohonen Nets.	2
7	Hopfield Nets and Boltzmann Machine.	2
8	Simple Word Vector Representations: Language Models, Softmax, Single Layer Networks.	2
9	Backpropagation for Named Entity Recognition.	1
10	Convolution Neural Networks: History, Convolution and Pooling, Convolution Net Outside Vision. CNN Architectures: Alex Net, Google Net etc. Shared Weight Networks. Introduction to Tensorflow. Introduction to NLP and Deep Learning.	9
11	Applications: Recurrent Neural Network for Language Modeling. GRU and LSTMs for Machine Translation. Recursive Neural Networks for Parsing. Convolution Neural Networks for Sentence Classification. The future of Deep Learning for NLP Dynamic Memory Networks. Neuropsychology for Computer Scientists. (Guest Lectures)	 2 2 2 2 1 2

Computational Topology (CS 5126)

Sl. No.	Topics	No. of Lectures
1	**Introduction** to point set topology, Metric spaces, Open and closed sets, Neighborhoods, Definition of Topology,Basis, for Topology, Continuous maps, Connectedness, Path-connectedness, Separation, Quotient Topology	6
2	**Graph:** Connected components, Curves and Knots, Planar graphs	4
3	**Surfaces:** Two-dimensional manifolds, Triangulation, Self-intersections, Surface simplification	4
4	**Complexes:** Simplicial complexes, Convex set systems, Delaunay complexes, Alpha complexes	6

5	**Homology:** Homology groups, Matrix reduction, Relative homology, Exact Sequences	4
6	**Persistence:** Persistent homology, Efficiet Implementation, Stability, Extended persistence, Spectral Sequence	6
7	**Morse Function:** Generic smooth functions, Transversality condition, Piecewise linear functions, Reeb graphs	6

References:

1. P. S. Alexandroff, Elementary Concepts in Topology, translated by A. E. Farley, Dover, New York.
2. H. Edelsbrunner, Geometry and Topology for Mesh Generation, Cambridge Univ. Press, England.
3. P. J. Giblin, Graphs, Surfaces and Homology, 2nd edition, Chapman and Hall, London.
4. Y. Matsumoto, An Introduction to Morse Theory, Amer. Math. Soc., Providence, Rhode Island.
5. J. W. Milnor, Topology from the Differential Viewpoint, Princeton Univ. Press, New Jersey.
6. J. R. Munkres. *Topology,* A First Course, Prentice-Hall, Englewood Cliffs, New Jersey.
7. J. R. Munkres, Elements of Algebraic Topology, Perseus, Cambridge, Massachusetts.

Cryptography and Network Security (CS 5127)

Sl. No.	Topics	No. of Lectures
1	**Attacks on Computers & Computer Security:** Introduction to Network Security, Motivation, Need for Security, Security approaches, Principles of Security, Types of attack, Threats in Networks, Network Security Controls.	2
2	**Cryptography: Basic Concepts & Techniques:** Introduction, Plaintext & Cipher text, Substitution Techniques, Transposition Techniques, Encryption & Decryption, Symmetric & Asymmetric key Cryptography, Key Range & Key Size, Mathematical foundations of cryptography.	5
3	**Symmetric Key Algorithm:** Introduction, Algorithm types & Modes, Overview of Symmetric Key Cryptography, Diffie-Hellman Key exchange algorithm and its analysis, Elliptic curve cryptography, Fiestel Cipher, Simplified-Data Encryption Standard (S-DES) algorithm, DES algorithm, Variety of DES, Advanced Encryption Standard (AES).	7
4	**Asymmetric Key Algorithm:** Introduction, Overview of Asymmetric key Cryptography, RSA algorithm, Knapsack Cipher, Message Authentication Codes and Digital Signature, Symmetric & Asymmetric key Cryptography together.	4
5	**Message Digests and Hash Functions:** Basic concepts of Message Digest, MD 5 algorithm, Basic concepts of Hash Functions, SHA-1 algorithm.	4
6	**Key Management and Certification Authority:** Digital Certificate, Certification Authority, Registration Authority, Steps involved in digital certificate creation, etc.	2
7	**IP Security:** Overview of IP Security (IPSec) and Virtual Private Networks (VPN), IP Security Architecture, Modes of Operation, Security Associations	5

	(SA), Authentication Header (AH), Encapsulating Security Payload (ESP), Internet Key Exchange.	
8	**Web Security:** Web Security Threats, Web Traffic Security Approaches, Overview of Secure Socket Layer (SSL) and Transport Layer Security (TLS), Overview of Secure Electronic Transaction (SET). Distributed system security - Kerberos Motivation, Kerberos Version 4 and 5, PGP – Notation and operational description.	5
9	**Network Defence:** Firewall Characteristics, Types of Firewalls, Comparison of Firewall Types, overview of Firewall Configuration	2
10	**Wireless Security:** Security threats to wireless network – rogue access point/Ad-hoc networks, Denial-of-service, configuration problems (misconfigurations/incomplete configurations), passive capturing. Protocols – WEP, WPA, WPA2.	4

References / Books:

1. "Cryptography and Network Security", William Stallings, 2nd Edition, Pearson Education Asia.
2. "Network Security private communication in a public world", C. Kaufman, R. Perlman and M. Speciner, Pearson.
3. "Cryptography & Network Security", Atul Kahate, TMH.
4. "Network Security Essentials: Applications and Standards", by William Stallings, Pearson.
5. "Designing Network Security", Merike Kaeo, 2nd Edition, Pearson Books.
6. "Practical Unix & Internet Security", Simson Garfinkel, Gene Spafford, Alan Schwartz, 3rd Edition, Oreilly.
7. Network Security : Kaufman , Perlman, Speciner, Pearson Education.

Paper - V (Open Elective)

Soft Computing (CS 5161)

Sl. No.	Module Name and Topics	No. of Hours
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,	10

	Hopfield Networks, Associative Memories, The boltzman machine: Working principles and Applications, Radial Basis function network, Recurrent neural network, current topics: Deep Learning, Applications.	
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 Simulated Annealing, Ant colony optimization,Tabu Search, and current topics.	10
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 Selection, Classifier.	5
6	**Hybrid Systems:** Integration of Artificial neural networks, Fuzzy logic, Rough set Theory and Evolutionary Algorithms, Applications	4

References /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", Goldberg, Pearson.

Image Processing and Pattern recognition (CS 5162)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction:** Importance and use of DIP, Historical perspective, Development and present state.	1
2	**Acquisition, Representation, Storage:** Sampling, Quantization, Basic Relationship Between Pixels and their neighborhood properties.	3
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	**Mathematical Morphology:** Morphological and other area operations, basic morphological operations, opening and dosing operations, dilation erosion, Hit or Miss transform.	3
5	**Image segmentation:** Edge linking and boundary detection, Hough transforms, graph-theoretic techniques, global and adaptive thresholding, Region based segmentation,	5
6	**Shape Representation and Description:** Chain codes, polygonal approximation, signatures skeletons, shape numbers, Fourier descriptor, statistical moments, topological descriptor, texture	4

7	**Image Compression:** Redundancies, Image compression modes, loss-less compression, lossy compression	4
8	**Pattern Recognition:** Introduction, overview of different approaches, decision boundaries, discriminant functions (linear and non-linear), Bayesian classification, training and test sets,parametric and non-parametric learning, minimum distance classifiers, k-NN rule, unsupervised learning, basic hierarchical and non-hierarchical clustering algorithms, dimensionality reduction, similarity measures, feature selection criteria and algorithms, principal components analysis, some applications.	11

References*:*

1. Digital Image Processing 3rd edition. Pearson Education. Rafael C. Gonzalez, Richard E. Woods.
2. Pattern recognition Principles: Jufus T. Tou, and Rafel C. Gonzalez, Addislon-Wesfy Publishing Company.
3. Digital Image Processing – William k. Prati -John Wiley edition.
4. Pattern classification. Richard Duda. Hart and David strok John Wiley publishers.
5. E. Gose, R. Johnsonbaugh and S. Jost: Pattern Recognition and Image Analysis, Prentice Hall of India.
6. T. Y. Young and K. S. Fu: Handbook of Pattern Recognition and Image Processing, Vols. 1and 2, Academic Press.
7. B. Chanda and D. Dutta Majumder: Digital Image Processing and Analysis, Prentice Hall of India.

Database Management System (CS 5163)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Database(DB), Database Management Systems, Database systems versus File systems, DB users, DB Administrators, Basic Schema of 3-schema Architecture, data independence, integrity, consistency.	3
2	Data Models: E-R model, Constraints, Cardinality constraints, Weak-entity types, Subclasses and inheritance, Specialization and Generalization, case study on E-R model	6
3	Data Model: Relational Model, ER to relational mapping, Relational Algebra, Query language SQL, Views, Integrity constraints, Specifying indexes, Embedded SQL.	8
4	Normalization and its importance, Functional Dependencies, 1NF to BCNF, Lossless decomposition, Dependency Preservation, Canonical cover of a Functional Dependency Set etc.	8
5	Issues in DBMS implementation: Security, Recovery and concurrency control, transaction management	8
6	Data Analysis: Data preprocessing, Clustering, Classification, case study	7

References:

1. A Silberschatz, H Korth, S Sudarshan, Database System and Concepts, 5th Ed., McGraw-Hill
2. C. J. Date, An introduction to database systems, Addision Wesley

Data Structure and Algorithm (CS 5164)

Sl. No.	Topics	No. of Lectures
1.	**Data structures:** Abstract data types (ADTs), vector, list, stack, queue, priority queue, trees, graph etc.	2
2.	**Algorithms:** Algorithm design, Algorithms and programs, basic idea of pseudo-code. Algorithm efficiency and analysis, time and space analysis of algorithms – order notations.	4
3.	**Linear Data Structures - Array and Linked list:** **Array :** Different representations – row major, column major. Sparse matrix - its implementation and usage. Array representation of polynomials. **Linked List:** Singly linked list, circular linked list, doubly linked list, linked list representation of polynomial and applications.	6
4.	**Linear Data Structures - Stack and Queue:** **Stack:** Stack and its implementations using array and linked list, applications. **Queue:** circular queue, dequeue. Implementation of queue- both linear and circular using array and linked list, applications.	5
5.	**Recursion:** Principles of recursion – use of stack, differences between recursion and iteration, tail recursion. Applications - The Tower of Hanoi, Eight Queens Puzzle.	3
6.	**Nonlinear Data structure - Tree:** Basic terminologies, forest, tree representation using array and linked list. Binary trees - binary tree traversal, threaded binary tree, expression tree. Binary search tree, Height balanced binary tree (AVL tree) B- Trees.	6
7.	**Non-linear Data Structure – Graph:** Graph definitions and concepts, Graph representations – adjacency matrix, adjacency list. Graph traversal – Depth-first search (DFS), Breadth-first search (BFS), applications. Minimal spanning tree – Prim's algorithm, Kruskal algorithm.	5
8	**Searching and Sorting Algorithms:** Sorting: Bubble sort and its optimizations, insertion sort, shell sort, selection sort, merge sort, quick sort, heap sort, radix sort. Searching: Sequential search, binary search, interpolation search.	6
9	**Hashing:** Hashing functions, collision resolution techniques.	3
	Total	**40**

References:

1. M. A. Weiss, "Data Structures and Algorithm Analysis in C", 2nd Ed, Pearson Edu. Asia.
2. Y. Langsam, M. J. Augenstein and A. M. Tenenbaum, "Data Structures using C", Pearson Education Asia
3. Richard F. Gilberg, Behrouz A. Forouzan, "Data Structures – A Pseudocode Approach with C", Thomson Brooks / COLE.
4. Aho, J. E. Hopcroft and J. D. Ullman, Data Structures and Algorithms, Pearson Edu. Asia.

Second Semester

Paper - VI (Departmental Core) - *Group D (Any one from the Group)*

Advanced Operating Systems (CS 5201)

Sl. No.	Topics	Hours
1	Review of introductory operating systems concepts, process management, inter-process communication, memory management, I/O systems, file systems, and the like	6
2	Use of the UNIX operating system interface and study of the architecture, design and implementaion aspect of Unix/Linux Operating System	10
3	Gaining experience in implementing and debugging operating system components, including the kernel module, system call, synchronization primitives, and the file system	6
4	**Distributed Operating system concepts:** Goals, Distributed Computing Models, Hardware Concepts, Software Concepts, Architecture of DOS. Design Issues: Transparency, Flexibility, Scalability, Reliability, Performance, fault tolerance	6
5	**Mobile OS:** Architecture, Android OS, iOS, Virtual OS, Cloud OS and their design issues	6
6	**Real Time Operating Systems: Characteristics of Real Time operating Systems, Classification of Real Time Operating Systems, Scheduling in RTOS.**	4

References:

1. Silberschatz, Galvin, and Gagne, Operating System Concepts Essentials, 9th Edition.
2. The Design of the UNIX Operating System. Maurice J. Bach
3. Unix Internal. Uresh Vahalia
4. Linux Kernel Development. Robert Love

Real Time Systems (CS 5202)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Introduction - Characteristics and Constraints, Hard Versus Soft Real-Time Systems	2
2	Hardware for Real-Time Systems - Processor Architecture, Memory Technologies, Architectural Advancements, IO Interfacing, Microprocessor versus Microcontroller, Distributed Architectures	3
3	Temporal Modeling and specification of real time systems: State diagram, finite automata model, petri-net, state chart and mode chart, Q-model, formal methods.	3
4	Real-Time Operating System - Kernel Design Alternatives	5
5	Real-time Scheduling (Uniprocessor scheduling): Basic concepts. Scheduling anomalies. Aperiodic task scheduling. Clock-based and priority-based scheduling of periodic tasks. Resource access protocols.	6
6	Real-time Scheduling: Multiprocessor/Multicore scheduling	4

7	Real-time Scheduling: Distributed scheduling	3
8	Real-time synchronization: uniprocessor protocols	4
9	Real-time synchronization: multiprocessor/multicore protocols	4
10	Time/utility function real-time resource management	8
11	Real-Time Operating System and Internet of Things	2
12	Real time systems analysis. Safety and reliability. Fault tolerance techniques. Performance analysis. Execution time prediction.	3
13	Real-Time Programming	4
14	Case Studies: FreeRTOS, RT Linux, Apache Mynewt, Atomthreads, Contiki	4

References /Books:

1. Real-Time Systems by Jane Liu
2. Real-Time Systems Design Principles for Distributed Embedded Applications by H. Kopetz

Paper - VII (Departmental Core) - *Group E (Any one from the Group)*

Advanced Database Management System (CS 5205)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Review of RDBMS:** Normal Forms, FDs, Decomposition and synthesis approaches, File organization, external sorting, Processing of joins, Query optimization, query transformation rules, DB transactions, ACID properties, interleaved executions, schedules, serializability, Recovery techniques, concepts of in-memory database	10
2	**Distributed Database Mgt. Systems:** Features of distributed vs. centralized database; levels of distribution transparency, Reference architecture, Fragmentation, Distribution transparency; Distributed Database Design, Framework, Design of Database fragmentation, Allocation of fragments; Equivalence transformations for queries, Transforming global queries into fragment queries; Distributed database transaction management, commit protocols, failure handling	15
3	**Object Oriented DBMS:** Creation and modeling of data as objects, relationship, identifiers, classes of objects, Type hierarchies and inheritance, Overview of Object Query language (OQL), Graph database	5
4	**Overview of Bigdata management and MongoDB**	5
5	**Overview of Mobile Database Systems**	5

Books Referred:

Text Books:

1. A. Silberschatz, H. Korth, S. Sudarshan, Database system concepts, 5/e, McGraw Hill.
2. S. Ceri, G. Pelagatti, Distributed Databases, Principles & Systems, McGraw Hill.
3. R. Elmasri, S. B. Navathe, Fundamentals of Database Systems, The Benjamin/ Cummings Publishing Company, Latest Edition.

Reference Books:

1. J.D. Ullman, Principles of Database Systems, Galgotia Publications Pvt. Ltd., Third Edition.
2. An Advanced Course in Database Systems, Beyond Relational Databases, S.W. Dietrich, S. D. Urban, Pearson Education.
3. Vijay Kumar, Mobile Database Systems, Wiley-Interscience.

Information Retrieval (CS 5206)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction to IR** Basic Techniques, Tokens and Terms, Architecture of a search engine	6
2	**Indexing** Static Inverted Indices, Query Processing, Index Compression, Dynamic Inverted Indices	8
3	**Retrieval Models and Ranking** Query processing; models, Probabilistic models, Language models, Text Processing, Link Analysis, Ranking Algorithms, Metalearning	10
4	**Retrieval Evaluation** Effectiveness measures, Efficiency measures	4
5	**Applications and Advance Topics** Web Search, Parallelization and MapReduce, Machine Learning for IR	6

References / Books:

1. Introduction to Information Retrieval. Christopher D. Manning, Prabhakar Raghavan, and Hinrich Schuetze, Cambridge University Press.
2. Search Engines: Information Retrieval in Practice. Bruce Croft, Donald Metzler, and Trevor Strohman, Pearson Education.
3. Modern Information Retrieval. Baeza-Yates Ricardo and Berthier Ribeiro-Neto. 2nd edition, Addison-Wesley.
4. Information Retrieval: Implementing and Evaluating Search Engines. Stefan Buttcher, Charlie Clarke, Gordon Cormack, MIT Press.

Paper - VIII (Departmental Core) - *Group F (Any one from the Group)*

Advanced Networking (CS 5209)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction:** Overview of computer networks, seven-layer architecture, TCP/IP suite of protocols Distributed System Introduction, Key characteristics, Motivation	5
2	**MAC protocols:** High-speed LAN, MAN, and wireless LANs, (For example, FDDI, DQDB, HIPPI, Gigabit Ethernet, Wireless Ethernet, etc.), Fast access technologies (For example, ADSL, Cable Modem).	9
3	**Network and Transport Protocol:**IPv6, basic protocol, extensions and options, Support for QoS, neighbour discovery, auto-configuration, routing, SCTP.	8
4	**Mobile Networks:** Overview of 3G and 4G cellular network. Network	14

	Architecture and Nodes familiarity. Mobility in networks. Mobile QoS. Mobile IP. Security related issues. Introduction to 5G cellular network. Introduction to Cellular IoT	
5	**Network security:** at various layers. Authentication header, Key distribution protocols. Digital signatures, digital certificates	4

References:

1. Behrouz Forouzan, Data Communications and Networking, 4th Ed., McGraw Hill.
2. James F. Kurose, Keith W. Ross, Computer Networking-A Top-Down Approach, 6th Ed.,Pearson
3. Jochen Schiller, Mobile Communications, Addison-Wesley

Distributed Systems (CS 5210)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	Computer architecture: CICS, RISC, Multi-core Computer networking: ISO/OSI Model Evolution of operating systems Introduction to distributed systems	4
2	Service models, naming and binding remote procedure calls (RPC), object brokers	6
3	Distributed Coordination, Temporal ordering of events, Lamport's logical clocks, Vector clocks; Ordering of messages, Physical clocks, Global state detection	6
4	Process synchronization, distributed transactions, mutual exclusion, election algorithms distributed shared memory and memory consistency models, distributed deadlocks	10
5	Distributed file system design, distributed file system case studies: NFS, AFS	6
6	Load scheduling and balancing techniques. Fault tolerance	4
7	Distributed database system : A Case study	4

References:

1. A. S. Tanenbaum and M. V. Steen, Distributed Systems: Principles and Paradigms, 6th Ed., Pearson-Prentice Hall.
2. A. D. Kshemkalyani and M. Singhal, Distributed Algorithms: Principles, Algorithms, and Systems, Cambridge University Press
3. M. L. Liu, Distributed Computing Principles and Applications, Pearson/Addison Wesley
4. George Coulouris, Jean Dollimore, Tim Kindberg, Gordon Blair, Distributed Systems - Concepts and Design, 5th Ed., Pearson

Paper - IX (Departmental Elective)

Embedded Systems for Secured Hardware Design (CS 5221)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction** Concept of embedded system. Processors and hardware unitsfor embedded	3

	system, embedded software, hardware –software co-design, system on chip	
2	**System specification and system analysis** Requirements, analysis, and modelling techniques	3
3	**System design techniques** Traditional approach, hardware software partitioning, system architecture, hardware synthesis, software design, optimization issues, POLIS co-design methodology	6
4	**Implementation platforms** Microcontrollers, DSP, PIC, FPGA	5
5	**Real time issues** System monitoring, RTOS, clock synchronization, wireless devices, parallelism	5
6	**Fault tolerance techniques** Fault tolerant design principles, redundancy, testing of embedded systems, time and data. Byzantine algorithm	5
7	**Hardware security** Issues of hardware security. Cryptographic hardware and their Implementation, optimization of cryptographic hardware on FPGA. Physically Unclonable Functions (PUFs), PUF implementations. Hardware Trojan: Operating modes, countermeasures, logic testing and side-channel analysis based techniques for Trojan detection	8
8	**System design Case studies** Fault-tolerance of cryptographic hardware. Modeling of arbiterPUFs	5

References:

1. Debdeep Mukhopadhyay and Rajat Subhra Chakraborty: Hardware Security: Design, Threats andSafeguards, CRC Press.
2. Ahmad-Reza Sadeghi and David Naccache (eds.): Towards Hardware-intrinsic Security: Theory andPractice, Springer.
3. Ted Huffmire et al: Handbook of FPGA Design Security, Springer.
4. Pak Chan et. al.: Digital Design Using FPGAs, Prentice Hall.
5. Jesse H. Jenkin: Designing with FPGAs and CPLDs, Prentice Hall.
6. Zainalabedin Navabi: VHDL. Analysis and Modelling of Digital Systems, McGraw-Hill

Natural Language Processing (CS 5222)

Module / Serial No	Topics	No. of Lectures
1	**Introduction to NLP:** Definition, issues and strategies, application domain, tools for NLP, Linguistic organisation of NLP, NLP vs PLP.	2
2	**Word Classes:** Review of Regular Expressions, CFG and different parsing techniques **Morphology:** Inflectional, derivational, parsing and parsing with FST, Combinational Rules **Phonology:** Speech sounds, phonetic transcription, phoneme and phonological rules, optimality theory, machine learning of phonological rules, phonological aspects of prosody and speech synthesis. **Pronunciation, Spelling and N-grams:** Spelling errors, detection and elimination using probabilistic models, pronunciation variation (lexical,	3 3 4 6

	allophonic, dialect), decision tree model, counting words in Corpora, simple N-grams, smoothing (Add-One, Written-Bell, Good-Turing), N-grams for spelling and pronunciation.	
3	**Syntax:** **POS Tagging:** Tagsets, concept of HMM tagger, rule based and stochastic POST, algorithm for HMM tagging, ransformation based tagging **Sentence level construction & unification:** Noun phrase, co-ordination, sub-categorization, concept of feature structure and unification.	4 3
4	**Semantics :** **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.	2 2 3 2
5	**Pragmatics:** Discourse: Reference resolution and phenomena, syntactic and semantic constraints on Coreference, pronoun resolution algorithm, text coherence, discourse structure **Dialogues:** Turns and utterances, grounding, dialogue acts and structures **Natural Language Generation:** Introduction to language generation, architecture, discourse planning (text schemata, rhetorical relations). Standardization using Unicode and Code Conversion.	4 2 4

References:

1. Diana Maynard, Kalina Bontcheva, Isabelle Augenstein, "Natural Language Processing for the Semantic Web", A Publication in the Morgan & Claypool Publishers series
2. Steven Bird, Ewan Klein and Edward Loper, "Natural Language Processing with Python", By O'Reilly
3. Christopher Manning and Hinrich Schütze, "Foundations of Statistical Natural Language Processing", The MIT Press

Computational geometry (CS 5223)

Sl. No.	Topics	No. of Lectures
1	Historical perspective: complexity notions in classical geometry. Towards computational geometry, geometric preliminaries, models of computation.	6
2	Geometric searching: point location problems, location of a point in a plannar subdivision, the slab method, the chain method, range - searching problems.	10
3	Convex hulls: problem statement and lower bounds. Graham's scan, Jarvis's march, quick hull technique, convex hulls in two and higher dimensions, extension and applications.	8
4	Proximity: divide and conquer approach, locus approach; the Voronoi diagram, Delauney triangulation, Arrangement and duality, triangulation of polygons lower bounds, variants and generalizations. Intersections, hidden-line and hidden surface problem.	8

5	The geometry of rectangles: application of the geometry of rectangles, measure and perimeter of a union of rectangles, intersection of rectangles and related problems.	4

References:

1. F. P. Preparata and M I. Shamos: Computational Geometry: An Introduction.
2. M. De Berg, M. Van Kreveld, M. Overmars and 0. Schwarzkopf: Computational Geometry: Algorithms and Applications
3. J. O'Rourke: Computational Geometry in C, Cambridge University Press, London.
4. K. Mehlhom and St. Naher: The LEDA Platform of Combinatorial and Geometric Computing.

Internet of Things and Cloud Computing (CS 5224)

Module / Sl. No.	Module Name and topics	No. of Lectures
1	**Introduction to IoT:** Architectural Overview; Design principles and needed capabilities; Basics of Networking - M2M and IoT technology fundamentals - devices and gateways; Data management; Business processes in IoT; Hardware Components- computing (Arduino, Raspberry Pi), communication, sensing, actuation, I/O interfaces; Software Components - programming APIs (using Python/Node.js/Arduino), communication and application protocols - MQTT, ZigBee, Bluetooth, Wi-Fi, CoAP, UDP, TCP.	9
2	**IoT Application Development & Case Study:** 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; IoT case studies: Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.	9
3	**Introduction to Cloud Computing** Overview of computing paradigm - recent trends, evolution of computing models; Introduction to cloud computing - NIST model, properties, characteristics, disadvanges, role of open standards; Service delivery models - IaaS, PaaS, SaaS; Deployment models - public, private, hybrid, community clouds; Architecture of cloud computing; Economy of scale issues; Pricing models in cloud.	6
4	**Advance Topics & Case Study** Virtualization - server, storage, network; Service and data management - server consolidation, MapReduce; Web Services - Web 2.0, Web OS; Service Level Agreement; Security issues in cloud; Case study: open source/commercial cloud.	12

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.
4. Ronald L. Krutz, Russell Dean Vines, "Cloud Security: A Comprehensive Guide to Secure Cloud Computing", Wiley-India.

5. "Cloud Computing: Principles, Systems and Applications", Editors: Nikos Antonopoulos, Lee Gillam, Springer

Quantum Computing (CS 5225)

Sl. No.	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

Reference Books:

1. Micheal A. Nielsen &Issac L. Chiang, "Quantum Computation and Quantum Information", Cambridge University Press, 10th Anniversary Edition
2. Phillip Kaye Raymond Laflamme Michele Mosca, "An Introduction to Quantum Computing", Oxford University Press

Graph Algorithms (CS 5226)

Sl. No.	Topics	No. of Lectures
1	Introduction to Graphs: Definitions of some basic terms, representation of graphs; Analysis of Algorithms	4
2	Graph Searching: BFS, DFS and their applications, finding connected components, bi-connected components, testing for bipartite graphs,	4

	finding cycle in graph.	
3	Planar Graphs: Basic properties, Planarity testing algorithm	4
4	Trees: Different MST algorithms, Kruskal's, Prim's	4
5	Paths in Graphs: Single source and all pair shortest path problem, Eulerian and Hamiltonian Graphs	4
6	Graph Matching: Algorithm for Matching in Bipartite Graphs, Algorithm for Matching in General Graphs	5
7	Networks: : The Max-flow min-cut theorem, max-flow algorithm	5
8	Graph Coloring: Vertex coloring, Edge Coloring, Total Coloring	5

References:

1. D.B. West, Introduction to Graph Theory, 2 nd Edition, PHI.
2. G. Chatrand and O.R. Oellermann, Applied and algorithmic Graph Theory, McGraw–Hill, Inc.

Big Data Analytics (CS 5227)

Module / Sl. No.	Topics	No. Of Lectures
1	**Introduction to Big Data** Big data: definition and taxonomy, value for the enterprise	2
2	**Big Data & Cloud Computing** Big data management in cloud, parallel database architectures: Google File System (GFS), BigTable, Dynamo, Datastore; Cloud-based parallel programming framework: introduction to Hadoop, components - MapReduce/Pig/Hive/HBase, loading data into Hadoop, handling files in Hadoop, getting data from Hadoop, querying Hadoop files	12
3	**Big Data & Machine Learning** Overview of machine learning; Introduction to machine learning tools for Big data - Spark & SparkML, H2O, Azure ML	6
4	**Recommender System** Content based recommendations: learning to rank for recommender systems (pointwise, pairwise, listwise), combining learning to rank with content based recommendations, case study - practice RankLib; Collaborative filtering: User based, Item based; Latent factor model: basic matrix factorization, probabilistic matrix factorization (PMF), case Study - PMF for restaurant recommendations; Evaluating recommender systems; Combining geographical and temporal dimensions for POI recommendations, diversifying recommendations, bundle recommendations	10
5	**Human Mobility Modeling** Management of human mobility data: grid indexing, quad-tree indexing, K-D tree indexing, rectangle tree-based indexing, range query and k-NN query, case Study - indexing POIs with R-tree; Modeling of human mobility data as matrices/tensors, graphs, documents, stochastic processes, case study - topic modeling, word embedding	10

Reference s /Books:

1. Chris Eaton, Dirk Deroos et al., "Understanding Big data", McGraw Hill.
2. Sherif Sakr, "Large Scale and Big Data: Processing and Management", CRC Press.

3. Kris Jamsa, “Cloud Computing: SaaS, PaaS, IaaS, Virtualization, Business Models, Mobile, Security and more”,Jones & Bartlett Learning Company LLC.
4. Seema Acharya, Subhasini Chellappan, "Big Data Analytics" Wiley.
5. Machine Learning by Tom Mitchell

Cyber Security & Forensics (CS 5228)

Module / Sl. No.	Topics	No. Of Lectures
1	**Cyber Security Concepts** Essential Terminologies: CIA, Risks, Breaches, Threats, Attacks, Exploits. Information Gathering (Social Engineering, Foot Printing & Scanning). Open Source/ Free/ Trial Tools: nmap, zenmap, Port Scanners, Network scanners.	3
2	**Infrastructure and Network Security** Introduction to System Security, Server Security, OS Security, Physical Security, Introduction to Networks, Network packet Sniffing, Network Design Simulation. DOS/ DDOS attacks. Asset Management and Audits, Vulnerabilities and Attacks. Intrusion detection and Prevention Techniques, Host based Intrusion prevention Systems, Security Information Management, Network Session Analysis, System Integrity Validation. Open Source/ Free/ Trial Tools: DOS Attacks, DDOS attacks, Wireshark, Cain & abel, iptables/Windows Firewall, snort, Suricata, fail2ban	8
3	**Cyber Security Vulnerabilities & Safe Guards** Internet Security, Cloud Computing &Security, Social Network sites security, Cyber Security Vulnerabilities-Overview, vulnerabilities in software, System administration, Complex Network Architectures, Open Access to Organizational Data, Weak Authentication, Authorization, Unprotected Broadband communications, Poor Cyber Security Awareness. Cyber Security Safeguards- Overview, Access control, IT Audit, Authentication. Open Web Application Security Project (OWASP), Web Site Audit and Vulnerabilities assessment.	10
4	**Security in Evolving Technologies** Biometrics, Mobile Computing and Hardening on android and ios, IOT Security, Web server configuration and Security. Introduction, Basic security for HTTP Applications and Services, Basic Security for Web Services like SOAP, REST etc., Identity Management and Web Services, Authorization Patterns, Security Considerations, Challenges. Open Source/ Free/ Trial Tools: adb for android, xcode for ios, Implementation of REST/ SOAP web services and Security implementations.	10
5	**Cyber Law & Forensics** Introduction, Cyber Security Regulations, Roles of International Law, the state and Private Sector in Cyberspace, Cyber Security Standards. The INDIAN Cyberspace, National Cyber Security Policy 2013. Introduction to Cyber Forensics, Need of Cyber Forensics, Cyber Evidence, Documentation and Management of Crime Sense, Image Capturing and its importance, Partial Volume Image, Web Attack Investigations, Denial of Service Investigations, Internet Crime Investigations, Internet Forensics, Steps for Investigating Internet Crime, Email Crime Investigations.	9

Reference s /Books:

1. William Stallings, “Cryptography and Network Security”, Pearson Education/PHI.
2. Matt Bishop, "Computer Security - Art and Science", Addison-Wesley.
3. Sarika Gupta, “Information and Cyber Security”, Khanna Publishing House, Delhi.
4. Nina Godbole, “Information System Security”, Wiley
5. Bothra Harsh, “Hacking”, Khanna Publishing House, Delhi.

Paper - X (Open Elective)

Data mining and Knowledge Discovery (CS 5261)

Sl. No.	Topics	No. of Lectures
1.	Introduction, Motivation and Functionalities of Data mining	2
2.	**Data Preprocessing:** Cleaning, Integration, Transformation, Reduction, Discretization, Concept hierarchy generation	6
3.	**Association Rule mining:** Market Basket Analysis, Frequent Items, Apriori Algorithm	4
4.	**Cluster Analysis:** Partition based clustering, Hierarchical Clustering, Density based clustering, Cluster Evaluation	8
5.	**Classification and Prediction:** Classification algorithms, Regression Models, Classifier Evaluation	6
6.	**Ensemble Classifier:** Bagging, Boosting, Random Forest, etc	6
7.	**Mining Text Databases:** Document preprocessing, clustering, Classification and Summarization	8
	Total	**40**

References:

1. Data Mining Concepts and Techniques by Jiawei Han, Micheline Kamber, Jian Pei
2. Introduction to Data mining by Pang-Ning Tan. Michael Steinbach. Vipin Kumar.

Information Security and Cryptography (CS 5262)

Sl. No.	Topics	No. of Lectures
1	**Attacks on Computers & Computer Security:** Introduction, Motivation, Need for Security, Security approaches, Principles of Security, Types of attack.	2
2	**Mathematical Background:** Shannon’s Theory, Computational Complexity, Finite Fields, Number Theory, Concept of Pseudo-Random Functions, Modes of Operation, Modular Arithmetic, Handling large prime numbers, Primality Testing Techniques, Factorization Methods.	5
3	**Cryptography - Basic Concepts & Techniques:** Introduction, Plaintext & Cipher text, Substitution Techniques, Transposition Techniques, Encryption & Decryption, Symmetric & Asymmetric key Cryptography, Key Range & Key Size.	3
4	**Symmetric Key Algorithm:**	6

	Introduction, Algorithm types & Modes, Overview of Symmetric Key Cryptography, Fiestel Cipher, Simplified-Data Encryption Standard (S-DES) algorithm, DES algorithm, Variety of DES, Advanced Encryption Standard (AES), RC5 (Rivest Cipher 5) algorithm.	
5	**Key Exchange:** Key exchange problem in symmetric key cryptography, Diffie-Hellman Key exchange algorithm and its analysis.	1
6	**Asymmetric Key Algorithm:** Introduction, Overview of Asymmetric key Cryptography, RSA algorithm, Knapsack Cipher, Symmetric & Asymmetric key Cryptography together.	4
7	**Message Authentication and Signatures:** Message Authentication Codes and Digital Signature.	2
8	**Message Digests and Hash Functions:** Basic concepts of Message Digest, MD 5 algorithm, Basic concepts of Hash Functions, SHA-1 algorithm.	4
9	**Cryptanalysis** Basic cryptanalysis techniques, Linear and Differential Cryptanalysis, Intractable (Hard) problems, Use of evolutionary algorithms in Cryptanalysis, etc.	4
10	**Key Management and Certification Authority:** Digital Certificate, Certification Authority, Registration Authority, Steps involved in digital certificate creation, etc.	3

References / Books:

1. "Cryptography and Network Security", William Stallings, 2nd Edition, *Pearson Education Asia.*
2. "Network Security private communication in a public world", C. Kaufman, R. Perlman and M. Speciner,*Pearson.*
3. "Cryptography & Network Security", Atul Kahate, *TMH.*
4. "Network Security Essentials: Applications and Standards", William Stallings, *Pearson.*
5. "Designing Network Security", Merike Kaeo, 2nd Edition, *Pearson Books*.
6. "Practical Unix & Internet Security", Simson Garfinkel, Gene Spafford, Alan Schwartz, 3rd Edition, *Oreilly*.

Computer Graphics (CS 5263)

Module / Sl. No.	Topics	No. of Lectures
1	**Introduction to computer graphics & graphics systems** Overview of computer graphics, digital representation of a picture, Graphic Displays: Random scan displays, Raster scan displays, Frame buffer and video controller, RGB color model, Interactive and Passive Graphics, Computer graphics software	4
2	**Primitive shape generation and area filling** Points and lines, line drawing algorithms: DDA algorithm, Bresenham's line algorithm, Midpoint line drawing algorithm. Midpoint circle generating algorithm, Midpoint ellipse generating algorithm, Fill algorithm: scan line polygon fill algorithm, boundary fill algorithm, flood fill algorithm, Soft filling.	6
3	**Geometric transformation and Viewing**	8

	Basic transformations: translation, rotation, scaling; composite transformation, reflection and shear, rotation about an arbitrary axis, reflection through an arbitrary plane, Window to viewport co-ordinate transformation, Clipping operations: Point clipping, line clipping, circle clipping.	
4	**Curves and surfaces** Curve representation, Bezier curves and B-spline curves, surfaces: Bezier surface and B-spline surface, Spheres, Ellipsoid, Blobby objects	4
5	**Visible surface detection** Floating horizon algorithm, Z-buffer algorithm, Ray tracing algorithm	3
6	**Color & shading models** Colour models – RGB, YIQ, CMY, HSV, HLS; Light sources – basic illumination models, – Ambient light, Diffuse reflection, Specular reflection, transparency, intensity attenuation	3
7	**Projection** Parallel projection and perspective projection, projection on an arbitrary plane	2
8	**Introduction to Animation concept** Animation: types, techniques, key frame animation, morphing, Virtual Reality concepts.	2

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.

Computer Control of Industrial Processes (CS 5264)

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	Discrete dynamical system representation	2
4	Z-transform and approximations	3
5	Concept of stability, Controllability and Observability criterion	4
6	Controller and observer design in the discrete domain	4
7	Concepts of estimation, prediction and smoothing	4
8	Ideas of optimal, adaptive and stochastic control	4
9	Real time integration and synchronization	5
10	Fault tolerance techniques and algorithms	5

References/Books:

1. Lamont and Houpis, Digital control system - theory, hardware, software
2. K Ogata, Discrete time control system
3. Arthur Gelb, Applied optimal estimation