NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

Revised Curriculum and Syllabi

Program Name

Master of Technology in Computer Science & Engineering

Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 02.08.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

Department of Computer Science & Engineering

Curriculum for M.Tech. in Computer Science & Engineering

First Semester

Sl. No.	Sub. Code	Subject	L-T-P	Credits	Hours
1	CS1001	Foundations of Computing Science	3-1-0	4	4
2	CS1002	Advanced Algorithms	3-1-0	4	4
3	CS1003	Distributed System	3-1-0	4	4
4	CS1004	AI & Machine Learning	3-1-0	4	4
5	CS90XX	Elective-I	3-0-0	3	3
6	CS1051	Advanced Computing Lab I	0-0-6	3	6
TOTAL				**22**	**24**

Second Semester

Sl. No.	Sub. Code	Subject	L-T-P	Credits	Hours
1	CS90XX	Elective-II	3-0-0	3	3
2	CS90XX	Elective-III	3-0-0	3	3
3	CS90XX	Elective-IV	3-0-0	3	3
4	CS90XX	Elective-V	3-0-0	3	3
5	CS90XX	Elective-VI	3-0-0	3	3
6	CS2051	Advanced Computing Lab 2	0-0-6	3	6
7	CS2052	Mini Project with Seminar	0-0-6	3	6
TOTAL				**21**	**27**

Third Semester

Sl. No.	Sub. Code	Subject	L-T-P	Credits	Hours
1	XX907X	Audit Lectures/ Workshops	0-0-0	0	2
	CS3051	Dissertation – I	0-0-24	12	24
2	CS3052	Seminar – Non-Project/Evaluation of Summer Training	0-0-4	2	4
TOTAL				**14**	**30**

Fourth Semester

Sl. No.	Sub. Code	Subject	L-T-P	Credits	Hours
1	CS4051	Dissertation – II/Industrial Project	0-0-24	12	24
2	CS4052	Project Seminar	0-0-4	2	4
TOTAL				**14**	**28**
Total Program Credit				**70**	**109**

LIST OF ELECTIVES (for M.Tech in Commuter Science & Engineering)

Pool –I (General Elective)

CS9011	Semantic Web and Linked Data Engineering	3-0-0	3
CS9012	Digital Image Processing	3-0-0	3
CS9013	Information & Coding Theory	3-0-0	3
CS9014	Advanced Optimization Techniques	3-0-0	3
CS9015	Mathematical Programming	3-0-0	3
CS9016	Quantum Information and Computing	3-0-0	3
CS9017	Cellular Automata	3-0-0	3
CS9018	Advanced DBMS	3-0-0	3
CS9019	Advanced Software Engineering	3-0-0	3
CS9020	Ethics, Society and Computer Science	3-0-0	3

Pool –II (Networks and Systems)

CS9021	Optical Networks	3-0-0	3
CS9022	Optical and Wireless Communication	3-0-0	3
CS9023	Wireless Networks & Mobile Computing	3-0-0	3
CS9024	Smartphone Computing	3-0-0	3
CS9025	High Performance Computing	3-0-0	3
CS9026	Wireless Ad Hoc and Sensor Networks	3-0-0	3
CS9027	Basics of IoT and Applications	3-0-0	3
CS9028	Cloud Computing	3-0-0	3

Pool –III (Data Sciences)

CS9029	Data Warehousing	3-0-0	3
CS9030	Data Mining	3-0-0	3
CS9031	Big Data Analytics	3-0-0	3
CS9032	Big Data Modelling and Management	3-0-0	3
CS9033	Statistical Learning for Data Science	3-0-0	3
CS9034	Business Process Modelling & Analysis	3-0-0	3
CS9035	Time Series Analysis	3-0-0	3
CS9036	Complex Network Theory	3-0-0	3

Pool –IV (AI & ML)

CS9037	Soft Computing Techniques	3-0-0	3
CS9038	Pattern Recognition	3-0-0	3
CS9039	Bio-Medical Signal and Image Processing	3-0-0	3
CS9040	Applied AI	3-0-0	3
CS9041	Introduction to Cognitive Computing	3-0-0	3
CS9042	Speech Processing	3-0-0	3
CS9043	Knowledge Based System Engineering	3-0-0	3
CS9044	Natural Language Processing	3-0-0	3
CS9045	Deep Learning	3-0-0	3
CS9046	Deep Learning for Image Processing	3-0-0	3
CS9047	Information Retrieval	3-0-0	3
CS9048	Human Activity Recognition	3-0-0	3

Pool –V (Computer Security)

CS9051	Foundations of Cryptography	3-0-0	3
CS9052	Cryptology and Cryptanalysis	3-0-0	3
CS9053	Biometrics	3-0-0	3
CS9054	Information and System Security	3-0-0	3
CS9055	Secure Multiparty Computation	3-0-0	3
CS9056	Digital Forensics	3-0-0	3
CS9057	Cyber Security	3-0-0	3
CS9058	Hardware Security	3-0-0	3
CS9059	Blockchain Technology and its Applications	3-0-0	3

Pool –VI (Software and Systems)

CS9061	Business Process Management in Software Science	3-0-0	3
CS9062	Ontology Engineering	3-0-0	3
CS9063	Software Testing	3-0-0	3
CS9064	Software Project and Quality Management	3-0-0	3
CS9065	Cloud Computing	3-0-0	3
CS9066	Software Architectures	3-0-0	3
CS9067	Agent based Systems	3-0-0	3
CS9068	Service-Oriented Systems	3-0-0	3

Pool –VII (Algorithms)

CS9071	Game Theory and its Applications	3-0-0	3
CS9072	Randomized Algorithms	3-0-0	3
CS9073	Computational Geometry	3-0-0	3
CS9074	Computability Theory	3-0-0	3
CS9075	Approximate Algorithms	3-0-0	3
CS9076	Computational Complexity Theory	3-0-0	3
CS9077	Computational Number Theory	3-0-0	3
CS9078	Data Stream Algorithms	3-0-0	3
CS9079	Online Algorithms	3-0-0	3
CS9080	Algorithmic Mechanism Design	3-0-0	3
CS9081	Theory of Parallel Systems	3-0-0	3
CS9082	Complex Network Theory	3-0-0	3
CS9083	Advanced Graph Theory	3-0-0	3

Pool –VIII (Architecture and Hardware Design)

CS9091	CAD for VLSI	3-0-0	3
CS9092	Cyber Physical Systems	3-0-0	3
CS9093	Advanced Computer Architecture	3-0-0	3
CS9094	Testing and Verification of Digital Circuits	3-0-0	3
CS9095	Hardware Security	3-0-0	3
CS9096	Embedded System Design	3-0-0	3
CS9097	High Performance Computing	3-0-0	3

DETAILED SYLLABUS

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS1001	Foundation of Computer Science	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
CSC301 (Discrete Mathematics)	CT+EA

Course Outcomes	
	• To help the student to gain the ability to use some of the fundamental methods of discrete mathematics in Computer Science. • To use these methods in a variety of sub-fields of computer science ranging from complexity theory, algorithms, machine learning, computer networks etc. • To use logical notation to define and reason mathematically about the fundamental data types and structures (such as numbers, sets) used in computer algorithms and systems • To construct complete formal proofs/arguments for a mathematical statement (theorem) • To understand the most important principles in design of computer hardware architectures in modern computer systems.

Topics Covered

Mathematics

Proof Techniques: Non-constructive proof**,** proof by contradiction, contrapositive proofs, Proof by Mathematical Induction- Coloring problem on line intersection graph, Well ordering principle, Pigeonhole principle, Ramsey number. Generating Functions - Counting with Generating Functions, Partial Fractions (6)

Introduction to Counting: r-Combination with repetition allowed – Counting iterations of a loop, Number of integral solutions of an equation; Catalan Number - Stack Permutation, Valid parenthesization, number of monotonic Manhattan paths, Convex polygon triangulation. (5)

Probability: Probability Spaces with Examples, Basic Rules of Probability, Uniform Probability Spaces, The Birthday Paradox, Throwing Balls into Boxes; The Big Box Problem, The Monty Hall Problem; Conditional Probability, Rolling a Die; The Law of Total Probability, Flipping a Coin and Rolling Dice, Independent Events, Rolling Two Dice, Pairwise and Mutually Independent Events; Describing Events by Logical Propositions - Flipping a Coin and Rolling a Die, Flipping Coins, The Probability of a Circuit Failing; Infinite Probability Spaces- Infinite Series, Who Flips the First Heads, Who Flips the Second Heads; Random Variables, Flipping Three Coins, Random Variables and Events, Independent Random Variables, Distribution Functions, Expected Values, Comparing the Expected Values of Comparable Random Variables, Linearity of Expectation, The Geometric Distribution and its Expected Value, The Binomial Distribution and its Expected Value, Indicator Random Variables, Largest Elements in Prefixes of Random Permutations, Expected number of swaps on random input in the Insertion-Sort Algorithm (10)

Optimization: Fundamentals, Applications of optimization, Statement of an optimization problem, Classification of Optimization problems, Optimization techniques, Linear Programming Problem (LPP)- formulation, Non-Linear Programming Problem (NLPP)- formulation, local and global optima, Concave and Convex functions, Unconstrained and Constrained NLPP, Modeling optimisation problems in SAT and SMT. (14)

Computer Architecture &Organizations:

PROCESSOR AND CONTROL UNIT: A Basic MIPS implementation – Building a Data path – Control Implementation Scheme – Pipelining – Pipelined data path and control – Handling Data Hazards & Control Hazards – Exceptions.
(10)

	MEMORY & I/O SYSTEMS: Memory Hierarchy – memory technologies – cache memory – measuring and improving cache performance – virtual memory, TLB's – Accessing I/O Devices – Interrupts. (5) **PARALLELISIM:** Parallel processing challenges – Flynn's classification – SISD, MIMD, SIMD, SPMD, and Vector Architectures – Hardware multithreading – Multi-core processors and other Shared Memory Multiprocessors – Introduction to Graphics Processing Units, Clusters, Warehouse Scale Computers and other Message-Passing Multiprocessors. (6)
Text Books, and/or reference material	Text Books: 1. C. L. Liu, Elements of Discrete Mathematics, Tata McGraw Hill 2. Norman L. Biggs, Discrete Mathematics, Oxford 3. Douglas B. West, Introduction to Graph Theory, Prentice Hall, India 4. G. Strang, Linear Algebra and Its Applications, Cengage Learning 5. S. S. Rao, Engineering Optimization: Theory and Practice, New Age International. 6. *Sheldon Ross, A First course in Probability*, University of Southern California, Pearson Education 7. David A Patterson, John L. Hennessy: Computer Architecture: A Quantitative Approach Reference Books: 1. Ronald L. Graham, Donald E. Knuth, and O. Patashnik, Concrete Mathematics, Pearson Education 2. Ronald L. Rardin, Optimizatipon in Operations Research, Pearson 3. John P. Hayes: Computer Architecture and Organization

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS1002	Advanced Algorithms	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Some course on Algorithms and Data structures, Discrete mathematics, Probability.		CT+EA					
Course Outcomes	• CO1: Can have the efficiency in the complexity analysis of the algorithms. • CO2: Detecting and applying the algorithmic structures in many different fields of engineering. • CO3: Will have the knowledge for state of the art development in the field of algorithms.						
Topics Covered	**Introduction to Algorithm** – Motivations, Asymptotic notations, solution to recurrence relations, Amortized running time complexity. (6) **Parallel Algorithms** – **(a)** Motivation for parallel algorithm, Parallel addition, Parallel implementation of Quick sort, Energy complexity of parallel algorithms - Derivation of asymptotic energy complexities of parallel algorithms, Analysis of parallel algorithms. **(b)** Selection problem - Sequential selection, Parallel selection on EREW SM SIMD machine and its analysis. **(c)** Searching problem - Parallel search - implementation of K-ary search and its analysis. **(d)** Graph algorithms - Parallel formulation for finding Connected components of a graph, finding Maximum Independent Set of a graph - parallel implementation. (12) **Advanced Data Structures** – van Emde Boas Trees, Augmented Data structure, Heavy hitters problem- Bloom filters and Count-Min sketch . (6) **Network Flow -** Flow networks, Augmenting paths, Ford- Fulkerson Algorithm, Edmonds - Karp algorithm, Max flow min-cut theorem, Push-relabel algorithm, Maximum bipartite matching, Some applications of network flow. (6)						

	Randomized Algorithm- Las Vegas and Monte Carlo algorithms, Five essential mathematical tools for Randomized algorithms: Linearity of expectation, Markov inequality, Chebyshev's inequality, Chernoff bound, and Union bound with examples to Randomized algorithm design. Examples and analysis of: Randomized Quick Sort, Min Cut problem, and Skip list. (6) **Online Algorithms:** Overview, Online scheduling and online Steiner tree, Online Bipartite matching, Online learning and multiplicative weights algorithm. (6) **NP- Completeness -** Classes of P, NP, NP-Hard, NP-Complete, Co-NP; Reduction ; Cook's Theorem, SAT, NP-Completeness proof of different problems: CLIQUE, VERTEX COVER, INDEPENDENT SET, SET COVER. (6) **Approximation Algorithms -** Constant factor approximation algorithm: VERTEX COVER and TSP; Christofides algorithm on TSP with 1.5 approximation factor; SET-COVER problem with log n factor approximation algorithm; PTAS and FPTAS, Linear programs and approximation algorithms. (8)
Text Books, and/or reference material	**Text Books:** 1. Rajeev Motwani and Prabhakar Raghavan, Randomized Algorithms, 2nd Edition, Cambridge University press, Cambridge, MA, 1995. 2. Thomas H. Cormen, Charles Leiserson, Ronald Rivest, and Clifford Stein. Introduction to Algorithms. 3rd ed. MIT Press, 2009, ISBN: 9780262033848. 3. S. G. Akl, The Design and Analysis of Parallel Algorithms, Prentice-Hall, 1989. 4. M. J. Quinn, Designing Efficient Algorithms for Parallel Computers, McGraw Hill Higher Education, 1987, ISBN: 978-0070510715. 5. J. Kleinberg and E. Tardos, Algorithm Design, Pearson. 6. D. V. Williamson and D. B. Shmoys, The Design of Approximation Algorithms, Cambridge University Press. 7. S. Arora and B. Barak, Computational Complexity: A Modern Approach, Cambridge University Press. **Reference Book/Lecture Notes:** 1. Dimitri P. Bertsekas and John N. Tsitsiklis, Introduction to Probability, 2nd Edition, Athena Scientific, July 2008. 2. M. Mitzenmacher and E. Upfal, Probability and Compuitng: Randomized Algorithms and Probabilistic Analysis, Cambridge University Press. 3. T. Roughgarden, CS261: A Second Course in Algorithms (Stanford University), 2016. 4. T. Roughgarden, CS168: Modern Algorithmic Toolbox (Stanford University), 2017.

<table>
<tr><th colspan="9">Department of Computer Science & Engineering</th></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS1003</td><td>Distributed Systems</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Operating Systems, Computer networks, Algorithm Design.</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To explain the paradigm of distributed computing.
CO2: To explore various existing and possible architectures of distributed systems.
CO3: To properly appreciate the issues that arise in distributed systems and explore solutions for the problems.
CO4: To fully appreciate the advantages to be obtained from a distributed environment wrt fault tolerance, load sharing etc.</td></tr>
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Topics Covered	Introduction to Distributed Systems. Motivations. Design Issues. (2) Message Passing, Buffering Techniques, Synchronization in Message Passing. (2) Group Communication, Ordered Message Delivery. (2) Remote Procedure Calls (RPC). (2) Clocks in a Distributed System. Synchronization Issues. Logical Clocks. Causal relationships. Vector Clocks. (3) Distributed State Detection. Global State. Consistent Cut. Global State recording algorithm. (4) Termination Detection. Credit based algorithm. Diffusion Computation based algorithm. (4) Distributed Mutual Exclusion. Token based and non-token based algorithms. (4) Deadlocks in Distributed Systems. Resource allocation Models. Deadlock Prevention. Deadlock Avoidance – Safe states. Deadlock detection and Correction. Phantom Deadlocks. Centralized, Distributed and Hierarchical deadlock detection algorithms (9) Fault Tolerance. Classes of Faults. Byzantine faults and Agreement Protocols. Distributed Commit Protocols. 2-phase commit. 3-phase commit. Election Algorithms. Bully algorithm. Ring topology algorithm. Fault recovery. Backward and Forward recovery. Log based recovery. Checkpoints. Shadow paging. Data Replication. Quorum Algorithms (9) Distributed File systems. Mechanisms. Stateful and Stateless servers. Scalability. Naming and Name Servers. (5) Distributed Scheduling. Load Balancing. Load Estimation. Stability. Process Migration. Binding. (3) Distributed Shared Memory. (2) Cloud Computing Architecture and Service Models. Security Issues. (3) Distributed Constrained Optimization (DCOP). (2)
Text Books, and/or reference material	**Text books** 1. Advanced Concepts in Operating Systems. Singhal and Sivaratri. McGraw Hill. **Refenence Books:** 1. Operating Systems : A Concept Based Approach. Dhamdhere. McGraw Hill. 2. Distributed Operating Systems : Concepts and Design. P.K.Sinha. Prentice Hall. 3. Distributed Operating Systems. A.Tanenbaum. Pearson Education. 4. Distributed Systems : Concepts and Design. Coulouris et.al. Pearson Education.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS1004	AI & Machine Learning	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Basic Concepts of Probability and Statistics.		CE+EA					
Course Outcomes	• CO1: Finding problems that can't be solved by if else method; • CO2: Different types of learning methods like Regression and Classification. • CO3: Machine learning algorithms like ANN, SVM and Decision Tree etc. • CO4: Deep Learning Methodologies like CNN, RNN and Reinforcement Learning.						
Topics Covered	**Introduction to AI and ML**: (2)						

	What is Intelligence, Reasoning and Planning, Learning and Adaptation, and interaction with the real world), A brief history of AI, Application areas of AI, State of the art. **Problem solving by search** (6) Problem types, Illustrative search problems; Search Space, Search tree; BFS, DFS, UCS, Completeness, optimality; Lookup tables. Greedy search, Local search; Hill climbing; Heuristics; A* search; Admissibility and consistency of heuristics, Game trees; Minimax search; Alpha-beta pruning; Genetic algorithms; **Knowledge Representation and Reasoning** (6) Propositional vs Predicate Logic, Reasoning Mechanism; Resolution and Theorem proving, Semantic Nets, **Probabilistic Reasoning** (6) Bayes Theorem, Bayesian Inference **Fuzzy Logic** (3) Fuzzy Systems and Reasoning **Neural Network** (4) Neurons and Perceptrons; Perceptron learning algorithm, FFN, Gradient descent; Backpropagation algorithm and MLP; **Supervised learning** (10) Decision Tree, Linear and Logistic Regressions, GLM and SoftMax Regression, Gaussian discriminant analysis, Naive Bayes Classifier, Support vector machines, K-NN. **Ensemble methods** (2) Bagging and boosting, Random forest, Ada Boost. **Unsupervised learning** (7) Clustering. K-means, EM, Mixture of Gaussians, Factor analysis, PCA (Principal components analysis), ICA (Independent components analysis). **Reinforcement learning and control** (4) MDPs. Bellman equations, Value iteration and policy iteration, Linear quadratic regulation (LQR), LQG, Q-learning. Value function approximation. **Deep Learning** (3) Basics of CNN and RNN. **Ethico-moral issues in AI and ML** (3) Algorithmic bias and Fairness issues, Moral issues in autonomous and intelligent systems, Narrow (or Weak) AI and General (or Strong) AI, Weaponization of AI.
Text Books, and/or reference material	Text Books: 1. Artificial intelligence: A Modern Approach- Stuart Russell, Peter Norvig, Prentice Hall, Fourth edition, 2020 2. Machine Learning - Tom M. Mitchell (TMH) 3. Applied Machine Learning- M. Gopal, McGraw Hill Education 4. Class Notes and Video Lectures – Prof. Andrew Ng, Stanford University

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td><td></td></tr>
<tr><td>CS1051</td><td>Advanced Computing Lab - I</td><td>Laboratory</td><td>0</td><td>0</td><td>6</td><td>6</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Basics of Algorithms and data structures, computer Networks and Operating Systems.</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To be able to understand the meaning of a computational model during implementation.
CO2: To have an idea of modern application of data structures and algorithms.
CO3: To implement networking protocols through small systems.
CO4 : To attain the ability to work in parallel platforms.
CO5 : To apply principles of distributed systems in practical implementations.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Assignments in Data Structures and Algorithms :
Hash tables (Consistent hashing, Locality-sensitive hashing, Bloom filters, Cuckoo hashing).
Data structures for combinatorial optimization: Fibonacci heaps, dynamic graph structures.
Search trees: Skip lists.
Self-adjusting data structures: Splay Trees.
Tries and suffix trees.
Geometric data structures.
Implementation of HITS and Page Rank algorithms
Implement the online advertisement problem as a bipartite matching problem.
Assignments in Parallel Systems :
Basics of MPI (Message Passing Interface)
Communication between MPI processes
Basics of OpenMP API
Sharing of work among threads using loop constructs in OpenMP.
Assignments in Networks and Distributed Systems :
TCP/IP Protocol Analysis using sniffer tool (Wireshark)
Install Wireshark in your machine.
https://www.wireshark.org/
https://www.wireshark.org/download.html
Getting started with Wireshark
https://www.youtube.com/watch?v=KYnbfYCkiOc</td></tr>
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Wireshark Tutorial for Beginners
https://www.youtube.com/watch?v=lb1Dw0elw0Q
http://www.cs.toronto.edu/~ahchinaei/teaching/2016jan/csc358/Assignment1w.pdf
https://www.wireshark.org/docs/wsug_html_chunked/ChapterIntroduction.html
(a) Write simple TCP and UDP program using socket API which will transfer simple text messages, and check TCP and UDP packets using Wireshark
(b)Using wireshark, capture the TCP headers while connecting your computer to the server of nit.dgp.ac.in.

2. Basic Socket Programming

The goal of this module is to implement a TCP client and server, and a UDP client and server

(a) Your TCP or UDP client/server will communicate over the network (same machine using local loop) and exchange data. The server will start in passive mode listening for a transmission from the client. The client will then start and contact the server (on a given IP address and port number). The client will pass the server a string (eg: “network”) up to 80 characters in length. On receiving a string from a client, the server should:
1) reverse all the characters, and
2) reverse the capitalization of the strings (“network” would now become “KROWTEN”).
The server should then send the string back to the client. The client will display the received string and exit.
(b) TCP and UDP Chat server-client communication program using Sockets

3. Flow Control Implementation

Implement naïve flow control mechanism using stop & wait protocol. Transfer files (Text, Image, Audio, Video) using TCP and UDP protocol. If during the connection suddenly connection is terminated then you have start ones again, it simply resume the process not start from being.

(a) Write a socket program in Java for Multimodal File Transmission using TCP and UDP with Full-Duplex Stop and Wait protocol. The program/protocol should support the following properties/mechanism
The protocol will send any type of files
Each packet should consist of the file name, sequence number/Acknowledgement number
A log file should be generated with some information like,
List of uncommon files in server and client which are to be transferred, Start time, If the connection is broken then the % of the file already uploaded, How many times connections were established during the complete transmission, End time (when the file is fully transmitted), How many packets are lost, How many time-outs are occurred, etc.

	4. **Sync Protocol Design** Sync is a communication protocol for peer-to-peer file sharing (P2P), which enables users to distribute data and electronic files over the Internet/offline in a decentralized manner. Implement lightweight sync protocol for Laptop, smartphone and Microcomputer devices using "nanhttpd" 5. **Application :** (a)Telemedicine Software Design Using "openvidu" [Openvidu is a opensource teleconferencing software] 6. Implementation of message queue (localhost processes) 7. Implementation of MPI/PVM over NFS. 8. Distributed Flooding and Multicasting. 9. Lamports Logical clock Implementation. 10. Single resource multiple process DME 11. RPC and Java RMI 12. Distributed Health Checking Programs 13. Leader election 14. Fault tolerance
Text Books, and/or reference material	**Text Book:** 1. Thomas H. Cormen, Charles Leiserson, Ronald Rivest, and Clifford Stein. Introduction to Algorithms. 3rd ed. MIT Press, 2009. ISBN: 9780262033848. 2. J. Kleinberg and E. Tardos, Algorithm Design, Pearson. 3. Advanced Concepts in Operating Systems. Singhal and Sivaratri. McGraw Hill. **Reference Book/Lecture Notes/Other Reference:** 1. T. Roughgarden, CS261: A Second Course in Algorithms (Stanford University), 2016 and Randomized Algorithms: COMS 4995 (2019) 2. T. Roughgarden, CS 168: The Modern Algorithmic Toolbox, Spring 2017. 3. Rajeev Motwani CS 361A - Autumn Quarter 2005-06 (Advanced Data Structures and Algorithms) 4. Stanford course on Data structures :CS166, 2016-21. 5. Leskovec, Rajaraman, Ullman, Mining of massive data sets: https://www.youtube.com/watch?v=xoA5v9AO7S0&list=PLLssT5z_DsK9JDLcT8T62VtzwyW9LNepV 6. Operating Systems : A Concept Based Approach. Dhamdhere. McGraw Hill. 7. Distributed Operating Systems : Concepts and Design. P.K.Sinha. Prentice Hall. 8. Distributed Operating Systems. A.Tanenbaum. Pearson Education. 9. Distributed Systems : Concepts and Design. Coulouris et.al. Pearson Education

Department of Computer Science and Engineering				
Course	Title of the		Total Number of contact hours	Credit

Code	course	Program Core (PCR)/ Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS1052	**Advanced Computing Lab - II**	Laboratory	0	0	6	6	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Machine Learning, DBMS, Software Engineering.	CT+EA

Course Outcomes	• CO1: To apply machine learning approaches in real problems • CO2: To explore the application of data science principles in handling data. • CO3 : To test software for fault identification and quality assurance.
Topics Covered	**Assignments for ML laboratory** 1. Assignment to execute Linear Regression with toy dataset 2. Assignment to execute Classification with toy dataset 3. Assignment to execute Softmax regression with handwritten number dataset 4. Assignment to classify emails(spam/non-spam) using Naive Bayes classification 5. Assignment to execute k-means clustering 6. Assignment for ANN, back propagation 7. Assignment to implement Deep Learning Algorithms to classify hand written numbers 8. Assignment to classify Images into k categories. **Assignments in Data Science** **Assignments in Software Testing** 1. Control Flow Graph based problems – to verify the McCabe Complexity, Independent Paths, Coverage (Statement, Branch, Predicates) and test case generation for a given program. [Tool: C++/Java/Python Language Compiler] 2. System Design related problems – ER/EER database design, UML Based system design including Use Case, Class Diagram, Sequence diagram, State Chart, Activity diagram etc. and system integration verifications [Tool: StarUML with ER Extension] 3. System Dynamics analysis using Petri-Net – Verification of System reachability, safeness, boundedness, Liveliness, Fairness, Reversibility properties. [Tool: CPN tool] 4. Cause Effect Graph (CEG) based testing problems: Generation of Decision tree for functional part of software, verify and test the relationship between a given result and all the factors affecting the result using CEG. 5. White Box Testing related problems: Loop Testing, Basis path testing, Coverage Testing [Tool: Junit/ TestNG] 6. Black Box Testing Related Problems: Equivalent Partitioning, Boundary Value Analysis, Decision Table based testing, All-pairs Testing [Tool: Junit/ TestNG] 7. GreyBox Testing Related Problems: Matrix Testing, Regression Testing, Orthogonal Array Testing (OAT) [Tools: JUnit/ NUnit/TestNG]

Text Books, and/or reference material	**Text Book:** 1. Artificial intelligence : A Modern Approach- Stuart Russell, Peter Norvig, Prentice Hall, Fourth edition, 2020 2. Machine Learning - Tom M. Mitchell (TMH) 3. C. J. Paul, Software testing: A craftsmen's approach, CRC Press , 2013 4. I. Somerville – "Software Engineering", Addison-Wesley **Reference Book/Lecture Notes/Other Reference:** 5. Applied Machine Learning- M. Gopal, McGraw Hill Education **6.** Class Notes and Video Lectures – Prof. Andrew Ng, Stanford University 7. S. Desikan, R. Gopalswamy, Software Testing: Principles and Practices, Pearson , 2006 **8.** G. J. Myers, The art of software testing, Wiley Interscience New York , 2011

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9055	Semantic Web and Linked Data Engineering	PCR	4	0	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Data structure, DBMS, Web Technology, Basic Computer Logic		CT+EA					
Course Outcomes	• CO1: Students can write their own semantic web page by using publicly available vocabulary. • CO2: Students can publish their data in Open Data format, such that the other people can discover it easily. • CO3: Students can able to develop semantic web application. • CO4: Students will get exposure in this topic for further higher studies and research.						
Topics Covered	Principles of Linked Data, Introduction, A Layered Approach. (4) Naming Things with URIs, Making URIs Dereferenceable. (5) The Semantic Web (SW) vision: What is SW? The difference between Current web and SW, SW technologies, the Layered approach. (7) The XML Language, Structuring, Namespaces, Addressing and Querying XML Documents. (7) Resource Description Framework, RDF syntax, RDF Schema (RDFS). (7) Construction RDF and RDFS: Different syntax implementation, How to Store into server, Construction of RDFS. (6) SPARQL: Query Language: Syntax and Query processing. (2) Web Ontology Language OWL: OWL Syntax and Intuitive Semantics, OWL Species. (6) Description Logics, Model-Theoretic Semantics of OWL. (4) Ontology Engineering: Introduction, Constructing Ontologies, Reusing existing Ontologies. (4) Protégé tools. (4)						
Text Books, and/or reference material	Text Books: 1. Semantic Web Primer: second edition by Grigoris Antoniou and Frank van Harmelen 2. Foundations of Semantic Web Technologies by Hitzler Pascal						

Text Books, and/or reference material	1. Ontological Engineering by Asunción Gómez-Pérez, Mariano Fernández-López, and Oscar Corcho 2. Linked Data: Evolving the Web into a Global Data Space by Tom Heath and Christian Bizer 3. Harald Sack semantic web videos

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90**	Digital Image Processing	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Linear algebra, Probability and statistics, Calculus, Mathematical Transforms.		CE+EA					
Course Outcomes	• CO1: To acquire the fundamental concepts of a digital image processing system • CO2: To understand the basic theory and algorithms and tools used for processing digital images. • CO3: To analyze 2D signals in the frequency domain through the Fourier transform • CO4: To know the applications and recent trends of digital image processing.						
Topics Covered	**Introduction to Digital Image Processing**: Introduction to Digital Image Processing & and Applications, Image digitization and sampling, Quantization, Matrix representation of digital image and Pixel relationships. (5) **Image Geometry and spatial Transformations:** Basic Transformations, Camera model and Image Geometry, Camera calibration and stereo imaging, Interpolation and resampling. (5) **Image Transformations:** Fourier Transform, Discrete cosine Transform, KL Transform. (5) **Image Enhancement:** Grey level transformation: Image negatives, Log transformations, Power-law transformations, Piecewise-linear transformations, Histogram Processing, Basics of spatial filtering: Smoothing spatial filters, sharpening spatial filters, Image enhancement in Frequency domain: Image enhancement in Frequency domain, Frequency domain smoothing filters, sharpening filters, Homo-Morphic filtering. (7) **Image restoration:** Degradation and noise model, Estimation of degradation function, Inverse filtering, MMSE (Wiener) filtering, Constraints least square filtering, Geometric Mean filters. (4) **Colour image processing:** Colour Models, Pseudo colour image Processing, Colour Transformations. Full colour image processing. (4) **Multi-resolution Analysis of Image**: Theory of wavelets, Theory of Sub-band coding, Discrete wavelet Transform. (4) **Image segmentation**: Detection of discontinuities, Edge linking and boundary detection, Thresholding, Region-based segmentation techniques. (5) **Morphological Image Processing:** Basic concept of set theories, Logical operation involving Binary images, Dilation, erosion, Opening and closing. Recent trends in digital image processing. (3)						
Text Books, and/or	**Text Books:** 9. R. C. Gonzalez and R. E. Woods, Digital Image Processing, Pearson, 2018. 10. A. K. Jain, Fundamentals of Image Processing, Prentice Hall, 1989.						

reference material	**Reference Books**: 1. Bernd Jähne, Digital Image Processing, 6th edition, Springer, 2005. 2. T. Acharya, A. K. Ray. Image Processing Principles and Applications, Wiley-Interscience, 2005.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 9017	Information & Coding Theory	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Probability and statistics, Abstract Algebra, Calculus		CT+EA					
Course Outcomes	• CO1: Understand the concepts Information Theory • CO2: Understand the application of Information Theory to Source Coding and Data Compression • CO3:Understand the methods of source coding and data compression • CO4: Understand the concept of channel coding and error correction techniques						
Topics Covered	**Information Theory:** Introduction, mathematical measure of information, average and mutual information and entropy. (4) **Source Coding and Data Compression**: Source coding theorem, Kraft inequality, properties of prefix codes, Shannon-Fano coding, Huffman coding, Lempel-Ziv codes, arithmetic coding, Rate distortion Theory, Lossless Predictive Coding, Lossy Predictive Coding, DPCM. (10) **Channel Capacity:** Discrete memoryless channel model, binary symmetric channels and channel capacity, entropy rate and channel coding theorem, information capacity theorem, Markov process and sources with memory. (5) **Error correction codes:** Introduction, basic concepts of linear algebra including group, ring, field, vector space etc. (2) **Linear Block Codes:** Definition, encoding and decoding of linear codes, generator matrix, error detection and correction, perfect codes, Hamming codes. (5) **Cyclic codes:** Definition, encoding and decoding, cyclic redundancy check. (3) **Convolution codes:** Encoding convolutional codes, generator matrices for convolutional codes, generator polynomials and graphical representation for convolutional codes. Viterbi decoder. (5) **Bose-Chowdhury-Hoquenghem codes:** Definition and construction of BCH codes, decoding SEC and DEC binary BCH codes, Reed Solomon codes. (4) **Trellis coded modulation:** Introduction, the concept of coded modulation, signal mapping and set partitioning, TCM decoder. (4)						
Text Books, and/or reference material	Text Books 1. Information Theory and Coding. N. Abramson. McGraw Hill 2. Elements of Information Theory. Thomas M. Cover and Joy A. Thomas. Wiley. 3. Error Control Coding. Shu Lin and Daniel J. Costello. Prentice Hall. 4. Coding Techniques. Graham Wade. PALGRAVE. Reference books 1. The theory of information and coding. R. J. McEliece. Cambridge. 2. Error Control Coding: From Theory to Practice. Peter Sweeney. John Wiley & Sons.						

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

<table>
<tr><td>CS90XX</td><td>Advanced Optimization Techniques</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pr-requisites</td><td colspan="6">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="2">Undergraduate mathematics: Theory of sets, Relations and functions, Linear algebra, logic and proof techniques, Basic knowledge of computer programming.</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• To cultivate an ability to formulate mathematical model for various complex system occurring in real world applications.
• To develop knowledge of the mathematical structure of the most commonly used linear and non-linear programming models.
• To understand the classical optimizations and its applications
• Ability to solve the constraint and convex optimization problems
• Able to perform sensitivity analysis and post processing of optimal solutions.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Basics of Optimization: Mathematical formulation (linear and non-linear); Engineering applications of optimization; Classification of optimization problems. 2L
Classical optimization (single and multi variable): Optimal criterion for single and multi-variable method; Region elimination methods; Gradient based methods for single variable; Unidirectional search, Direct search methods, Gradient based methods for multi-variable. 8L
Constraint Optimization: problem preparation, Kuhn-Tucker Conditions, Lagrangian Duality Theory, Transformation Methods- Penalty Function Method, Method of Multipliers ; Sensitivity Analysis; Direct Search for Constrained Minimization; Linearization methods for constraint problems; Feasible Direction Method; Generalized Reduced Gradient Method and Gradient Projection Method. 8L
Goal Programming: Concept of goal programming, Modeling Multiple objective problems, Goal programming model formulation (Single goal with multiple sub goals, equally ranked multiple goals, Priority ranked goals, General goal programming models), Graphical method of goal programming, Post optimal analysis. 6L
Stochastic Programming: Stochastic programming with one objective function. Stochastic linear programming. Two stage programming technique. Chance constrained programming technique. 6L
Geometric Programming: Posynomial; Unconstrained GPP using differential Calculus; Unconstrained GPP using Arithmetic – Geometric Inequality; Constrained GPP. 6L
Network Analysis in Project Planning: PERT and CPM with activity times known and probabilistic. Various types of floats, Project crashing. Formulation of CPM as a linear programming problem. Resource leveling and resource scheduling. 6L</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. S. S. Rao, Engineering Optimization: Theory and Practice, New Age International.
2. K. Deb, Optimization for Engineering Design, Prentice Hall of India.
3. A. Ravindran, K. M. Ragsdell and G. V. Reklaitis, Engineering Optimization: Methods and Applications, Wiley.
4. Hillier & Lieberman, Introduction to Operations Research, TMH
Reference Books:
1. S. M. Sinha, Mathematical Programming, Elsevier
2. Handy A Taha, Operations Research – An Introduction, Prentice Hall of India, New Delhi.
3. R. Fletcher, Practical Methods of Optimization, Wiley.</td></tr>
</table>

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90XX	Mathematical Programming	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Undergraduate mathematics: Theory of sets and functions, Linear algebra, logic and proof techniques, Basic knowledge of computer programming.	CT+EA

Course Outcomes	• To understand the basic theory and methods for linear programming problems • To understand the basic properties of the interior point method and how to use it to solve convex optimization problems • To cultivate an ability to formulate mathematical model for various complex system occurring in real world applications. • To develop knowledge of the mathematical structure of the most commonly used linear and non-linear programming models. • Able to perform sensitivity analysis and post processing of optimal solutions.
Topics Covered	Introduction: Background, linear programming, non-linear programming, linear transformations, system of linear equations, convex and concave functions. [5] Linear Programming Problem: Linear programs formulation, preliminary theory and geometry of linear programs, basic feasible solution, different form of LPP; Graphical representation and solutions; Simplex method - variants of simplex method; Duality and its principles- interpretation of dual variables, dual simplex method, primal-dual method; Degeneracy in LPP; Sensitivity analysis; Transportation problems; Assignments problems; Decomposition principle for linear programs; Ellipsoid and Interior point method. [17] Network Flow Models: Basics of network models, Shortest route problem-formulation and algorithms; Maximal flow model; CPM and PERT. [8] Non-Linear Programming Problem: Formulation of NLPP; Lagrange multipliers, Constraint qualification, KKT optimality conditions, sufficiency of KKT under convexity; Quadratic programs- Wolfe method; Separable programming, Non-convex programming. [12]
Text Books, and/or reference material	Text Books: 1. S. M. Sinha, Mathematical Programming-Theory and Methods, Elsevier. 2. Dimitris Bertsimas and John Tsitsiklis, Introduction to Linear Optimization by, MIT 3. H. Taha, Operation Research – An Introduction, Prentice Hall of India. 4. Bazaraa, Sherali and Shetty, Nonlinear Programming: Theory and Algorithms, Wiley, 2006, Reference Books: 1. S. S. Rao, Engineering Optimization: Theory and Practice, New Age International 2. Hillier & Lieberman, Introduction to Operations Research, TMH. 3. Boyed and Vandenberghe, Convex Optimization. Cambridge 4. MIT Open Courseware, Introduction to Mathematical Programming (https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-251j-introduction-to-mathematical-programming-fall-2009/)

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	Title of the course		Total Number of contact hours	Credit

Course Code		Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90**	**Quantum Information and Computing**	PEL	3		0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Design and Analysis of Algorithms/Information and Coding Theory /Quantum Mechanics	CT+EA **[CA: 15%, MT: 25%, ET: 60%]**
Course Outcomes	• CO1: Understanding the fundamental concepts of Information Theory and Quantum System • CO2: Understanding different Quantum Gates and Circuits • CO3: Teleportation of information in Quantum System • CO4: Implementation of Quantum Computing for information processing • CO5: Understanding information security by Quantum Cryptography
Topics to be Covered (40L)	1. Classical Information Theory (2L) Information Theory, Shannon's Entropy, Grouping Theorem, Gibb's Inequality, Communication Systems, Coding, Shannon's Theorem 2. Quantum Information and Computing – I (2L) Introduction, Postulates of Quantum Mechanics [5 Postulates] , The Qubit, Bloch Sphere Representation of Qubits, Composite Systems, Linear Algebra(Projection Operator, Spectal Theorem, Positive Operator, Polar Decomposition of an Operator, Singular Value Decomposition) 3. Quantum Information and Computing - II (Density Matrix Formulation & Quantum Mechanics) (2L) Introduction, Density Matrix Mixed, State Density Matrix, Density Matrix & Block Sphere, Postulates of Quantum Mechanics - in Density Matrix Representation, Reduced Density Matrix, Schmidt Decomposition ad Schmidt number, Purification 4. Multiple Qubit States and Quantum Gates (2L) Introduction, Composite Systems, Matrix Basis in the Space of Two Qubits, Single Qubit Gates, Different Single Qubit Gates (Pauli Matrices, Hadamard), Two Qubit Gates, Three Qubit Gates 5. Quantum Circuits (2L) Introduction, Implementation of Classical Logic Gates, Oracle 6. No-Cloning Theorem and Teleportation (2L) Introduction, Quantum No-cloning Theorem, Quantum Teleportation 7. Super Dense Coding (2L) Introduction, Dense Coding Circuit 8. Measurement postulates (2L) Introduction, Measurement Postulates, Projection on Von-Neumann Measurement , Measurement in a Mixed State, POVM 9. Simple Quantum Algorithms - Deutsch Algorithm and Deutsch - Jozsa Algorithms (2L) Introduction, Quantum Parallelism, Collapse of Wave Function and Process of Measurement, Entanglement, Quantum No-Cloning Theorem, Deutsch Problem, Deutsch - Jozsa Algorithm 10. Simon Problem (1L) Introduction , Simon Problem , Classical Complexity ,Quantum Circuit for Simon Problem 11. Grover's Search Algorithm (2L) Introduction , The Oracle , Grover Operator and its Geometric Inter predation , Maximum Number of Iteration, Matrix Representation of Grover Operator , Quantum Circuit , Success and Failure of Algorithm to Example , The Quadratic Speeding , Maximum Number of Iteration , Matrix Representation of Grover Operator , Quantum Circuit , Success and Failure of the Algorithm to Example 12. Quantum Fourier Transform (2L)

	Introduction , Discrete Integral Transforms , Quantum Fourier Transform , Period Finding , Unitary Operator for QFT , Implementation , QFT for 3 Qubits 13. Shor's Factorization Algorithm (2L) Introduction, Shor's Algorithm , Implementation of Quantum Computation Part , Method of Continued Fraction 14. Classical Information Theory Revisited (1L) 15. Shannon Entropy (1L) 16. Von-Neumann Entropy (1L) 17. EPR and Bell's Inequality (2L) Introduction , Bell States and Local Measurement, Bell's Inequalities ,CHSH Inequality 18. RSA Algorithm (2L) Introduction , Fermat's Little Theorem , Euler's Theorem , Chinese Remainder Theorem , RSA Encryption and Decryption , Euclid's Algorithm , Extended Euler's Algorithm 19. Quantum Cryptography (2L) Introduction , BB-84 Protocol , Eve's Interception ,B-g2 Protocol , Ekert Protocol using EPR Pairs (E-D1), 20. Quantum Error Correction (2L) Introduction , Errors in Classical Communication , Errors in Quantum Communications , Three Qubit Error Code for Bit Flip Errors , Generating Logical Qubits, Corrective Steps Taken by Bot, Shor's 9-Qubit Code , Conversion of Phase Error to Bit Error , Shor's9 Qubit Code – Encoding, The Decoding Circuit
Text Books, and/or reference material	**Text Books:** 1. Quantum Computation and Quantum Information, by Michael A. Nielsen , Isaac L. Chuang, Cambridge Press 2. An Introduction to Quantum Computing, by Phillip Kaye , Raymond Laflamme , Michele Mosca, Oxford Press 3. The Feynman Lectures on Physics - Vol.3, by Richard P. Feynman, Pearson Publishing

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90**	**Cellular Automata and Its Applications**	PEL	3		0	3	3
Pre-requisites			Course Assessment methods (Continuous (CT) and end assessment (EA))				
Design and Analysis of Algorithms/Information and Coding Theory /Quantum Mechanics			CT+EA **[CA: 15%, MT: 25%, ET: 60%]**				
Course Outcomes	• CO1: Understanding the fundamental concepts of Cellular Automata • CO2: Understanding the different phases of evolution of CA machine. • CO3: Understanding the method of characterization of CA machine/tool • CO4: Modeling of physical/real-time systems with a mathematical tool such as CA. • CO5: Applying suitable class of CA for building CA based model to study						
Topics to be Covered (40L)	**1. Cellular Automata (4L)** Introduction-Cellular Automata, Evolution: Von Neumann Structure, Garden-of-Eden theorem, Hedlund's theorem, Conservation laws, Universal computing, Game of Life						

	2. **Characterization of CA Behavior (6L)** Initial Phase of Development, CA-Based Models - Language Recognizer, Biological Applications, CA as Parallel and Image Processing Systems, CA based model of physical systems 3. **New Phase of CA Model: Wolfram's Structure (8L)** Wolfram's model of CA, 3-neighborhood 2-state CA, CA rules, Classification of rules, CA Technology, CA as an FSM, Linear/non-linear/additive CA, Polynomial Algebraic Characterization of CA Behavior, Matrix Algebraic Characterization , Synchronous and asynchronous CA, Fixed point Graph, Reachability Tree, ERVG diagram **4. Irreversible/Group CA characterization in linear domain (6L)** Null/Periodic boundary Characterization of the State-Transition Behavior, Cycle Set Characterization, Isomorphism between a CA and an LFSR. CA based Pseudorandom Pattern Generation, Pseudo noise sequence, CABIST, Pattern Classification. **5. Characterization of non-group CA/non-invertible CA in linear domain** (6L) General Characterization of Cyclic States (attractors), Characterization of Single Length Cycle Single Attractor CA (SACA), Multiple-Attractor Cellular Automata (MACA). 6. **Non-linear CA (6L)** Characterization of non-linear rules, invertible and non-invertible CA, CA with point states; applications in VLSI domain: Test Hardware Design, Self Testable Hardware Design, Fault Tolerant Circuit Design, Memory Testing **7. Advanced Concepts (6L)** Extension of dimension, d-state CA, Application in IOT and health informatics, follow-up and review.
Text Books, and/or reference material	**Text Books:** **1.** Additive Cellular Automata: Theory and Applications**,** by Parimal Pal Chaudhuri, Dipanwita Roy Chowdhury, Sukumar Nandi, Santanu Chattopadhyay, Wiley. 2. Cellular Automata Machines: A New Environment for Modeling- by Norman Margolus and Tommaso Toffoli 3. Cellular Automata and Complexity: Collected Papers by Stephen Wolfram; Westview Press **Reference Books:** 1. Game of Life Cellular Automata, by Andrew Adamatzky, Springer; 2010 Edition. 2. A New Kind of Science, by Stephen Wolfram, Wolfram Media. 3. A New Kind of Computational Biology, by Chaudhuri, P.P., Ghosh, S., Dutta, A., Choudhury, S.P; Springer. 4. Cellular Automata: A Discrete View of the World by Joel L. Schiff

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Advanced Database Management Systems	PEL	3	0	0	3	3

Pre-Requisite: Database Management Systems	Course Assessment methods (Continuous (CT) and end assessment (EA))
	CT+EA

Course Outcomes	• CO1: To understand the basic concepts and terminology related to DBMS and Relational Database Design • CO2: To the design and implement Distributed Databases. • CO3:To understand advanced DBMS techniques to construct tables and write effective queries, forms, and reports
Topics Covered	**Introduction:** Comparison between different databases: Significance of Databases, Database System Applications, Advantages and Disadvantages of different Database Management systems, Comparison between DBMS, RDBMS, Distributed and Centralized DB, Introduction of various types of index structures: Primary, Secondary, Multilevel, Dynamic multilevel (B-tree and B+- tree). (3) **Normalization:** Functional Dependency, Anomalies in a Database, The normalization process: Conversion to first normal form, Conversion to second normal form, Conversion to third normal form, The boyce-code normal form (BCNF), Fourth Normal form and fifth normal form, normalization and database design, Denormalization, Loss-less join decomposition, Dependency preservation. (4) **Transaction processing:** Introduction of transaction processing, advantages and disadvantages of transaction process system, online transaction processing system, serializability and recoverability, view serializability, Transaction management in multi-database system, long duration transaction, high-performance transaction system. (3) **Concurrency Control:** Serializability, Serializability by Locks, Locking Systems with Several, Lock Modes, Architecture for a Locking Scheduler Managing Hierarchies of Database Elements, Concurrency Control by Timestamps, Concurrency Control by Validation, Database recovery management. (4) **Query Optimization & Query Execution:** Algorithm for Executing Query Operations, External sorting, select operation, join operation, PROJECT and set operation, Aggregate operations, Outer join, Heuristics in Query Optimization, Converting Query Tree to Query Evaluation Plan, Efficient and extensible algorithms for multi-query optimization, Introduction to Physical-Query-Plan Operators, One-Pass Algorithms for Database, Operations, Nested-Loop Joins, Two-Pass Algorithms Based on Sorting, Two-Pass, Algorithms Based on Hashing, Index-Based Algorithms, Buffer Management, Parallel Algorithms for Relational Operations, Using Heuristics in Query Optimization. (6) **Distributed Database (DDB):** Introduction of DDB, DDBMS architectures, Homogeneous and Heterogeneous databases, Distributed data storage, Advantages of Data Distribution, Disadvantages of Data Distribution Distributed transactions, Commit protocols, Availability, Concurrency control & recovery in distributed databases, Directory systems, Data Replication, Data Fragmentation. Distributed database transparency features, distribution transparency. (5) **Object Oriented DBMS(OODBMS):** Overview of object: oriented paradigm, OODBMS architectural approaches, Object identity, procedures and encapsulation, Object oriented data model: relationship, identifiers, Basic OODBMS terminology, Inheritance , Basic interface and class structure, Type hierarchies and inheritance, Type extents and persistent programming languages, OODBMS storage issues. (5) **XML Query processing:** XML query languages: XML-QL, Lorel, Quilt, XQL, XQuery, and Approaches for XML query processing, Query processing on relational structure and storage schema, XML database management system. (3) **Data Warehousing:** Overview of DW, Multidimensional Data Model, Dimension Modelling, OLAP Operations, Warehouse Schema (Star Schema, Snowflake Schema), Data Warehousing Architecture (3) **Big Data:** Motivation, Big data storage systems, MapReduce paradigm, streaming data, Graph database (3) **Advanced database applications:** Multimedia database, Geographical Information System (GIS) (3)

Text Books, and/or reference material	**Text Books:** 1. C. J Date, Pearson Education, "An Introduction to Data Base Systems". 2. Abraham Silberschatz, Henry F. Korth and S. Sudarshan, McGraw-Hill,"Database System Concepts". 3. Stefano Ceri and Giuseppe Pelagatti, McGraw-Hill International Editions."Distributed Databases Principles & Systems". 4. Ramez Elmasri and Shamkant B. Navathe, Addison-Wesley, "Fundamentals of Database Systems"

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 91XX	Advanced Software Engineering	PEL	3	0	0	3	3
		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• CO1: To acquire an understanding of the Software Process & Methodologies • CO2: To learn about Software Design mechanisms both for traditional and Object Oriented system • CO3: To obtain a comprehensive idea of different software Testing strategies • CO4: Development of cumulative understanding of software Project Management and Quality Metrics.
Topics Covered	Software Paradigm / Introduction: Definition of Information System, software, software engineering paradigms, Software engineering in context of Business Process Engineering, Goal of Software Engineering, Quality focus. (2L) Software Process Model: Umbrella activities; Waterfall Model, Prototype model, Rapid Application Development Model, Evolutionary Approach in Process model (Spiral Model) (2L) Requirement Engineering: Requirements Engineering Tasks, Information Modelling (Entity Relationship Model, Extended ER Model), Functional Model (DFD, CFD), Behavioral Model (State Transition Diagram), Petri-net modelling, System Requirement Specification (SRS), Specification Language – Formal Methods, Regular Expression, Decision Tree, Decision Table, SRS Standards (4L) Design Principle and Basics: Design level tasks, Problem partitioning, abstraction, top down & bottom up design strategies, refinement techniques, Minor Design principles, Control Hierarchy (Structured Chart), constraint design (Warnier –Orr). (4L) UML basics: Unified Modelling Language – Building Blocks, Well-formedness rule; Use case, structural diagram introduction - Class Diagram, Object Diagram, Sequence diagram, collaboration diagram. (6L) Modular Design: Concept of module and Modular design, Functional independency, Cohesion, Coupling, measuring cohesion and coupling. (2L)

	Architecture Basic: Software architecture, Functional and extra-functional properties, families of related system, Architectural styles: Data-centric, data-flow, call and Return, layered, enterprise. (2L) MDA & DSMA – Model Driven Architecture – Computationally independent model (CIM), Platform independent model (PIM), Platform Specific Model (PSM), Meta-object Factory. Domain Specific Modeling – Meta-meta-modelling, Meta-modelling, Modelling and System Modelling, Domain specific modeling language properties. (2L) Project Management: LOC●Function Point Analysis●PERT Chart estimation●Different cost estimation: Delphi-empirical-COCOMO estimation. (2L) Coding Techniques & Standard guidelines: Rules/guidelines for standard Coding ● Gunning Fog Index for documentation. (2L) Testing strategy 1– Introduction to Software Testing● Software Testing Terminology and Methodology● Verification and Validation● Static Testing: Inspections, Structured Walkthroughs, Technical Reviews ● Dynamic Testing : Black-Box Testing Techniques: Boundary Value Analysis (BVA), Equivalence Class Testing, State Table-Based Testing, Decision Table-Based Testing, Cause-Effect Graphing Based Testing, Error Guessing ● Dynamic Testing : White-Box Testing Techniques: Need of White-Box Testing, Logic coverage Criteria, Basis Path Testing, Graph Matrices, Loop Testing, Data Flow Testing, (4L) Testing strategy 2- Validation Activities: Unit Validation Testing, Integration Testing, Function Testing, System Testing, Acceptance Testing ●Regression Testing: Progressive vs Regressive Testing, Regression Testability (2) (2L) Advanced Testing: Fault based testing: Mutation Testing ● Testing Objet-Oriented Software: OOT Basics, Object-oriented Testing: MM testing, Function Pair Testing. ● Traditional Software and Web-based Software, Challenges in Testing for Web-based Software ● Debugging: Debugging Techniques, Debuggers ● Test Adequacy Measurement and Enhancement: Control and Data flow. (4L) Software & Metrics: Software Measurement & metrics, Direct and indirect metrics, Size oriented metrics, Function oriented Metrics, Complexity Metrics – McCabe Complexity, McClure Complexity, and Halstead Software Science. (4L)
Text Books, and/or reference material	Text Books: 1. R. S. Pressman -"Software Engineering – Practitioner's Approach"- McGraw Hill International 2. I. Somerville – "Software Engineering", Addison-Wesley

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS90**	Ethics, Society, and Computer Science	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
Basic knowledge of programming and AI/ML		CA+ MT + ET [CA: 15%, MT: 25%, ET: 60%]					

Course Outcomes	• CO1: To understand professional and ethical responsibilities, including those defined in the ACM/IEEE Professional Code of Ethics. • CO2: To ensure fairness, accountability, and transparency while working on machine learning, artificial intelligence and related fields. • CO3: To appreciate the threats to privacy posed by modern data aggregation and data processing techniques. • CO4: To design technologies incorporating ethical considerations from the specification provided.
Topics Covered	**Introduction:** What is Ethics?, Ethics and Computer Science, Social consensus on unethical practices by computer professionals, Conventional issues, Emerging issues in the age of data driven (AI/ML based) decision making, History and Evolution of ethics with advances in computer science and engineering. (4L) **Ethics in Data collection and aggregation:** Basic mechanism of data driven (AI/ML based) decision making, Data aggregation and decision making, Data Ownership, Collection and collation of digital imprints of users, Data stealing and data broking, Informed consent, Data repurposing, Privacy, Anonymity, Data validity, Establishing data protection framework with legal backing, Concept of differential privacy, GPDR. (10L) **Algorithmic Fairness:** Discriminatory impact of imperfect decisions, Case study: Facial recognition software, Criminal justice using big data, recidivism models for sentencing guidelines, predictive policing, Trust in AI/ML based decision making, Algorithmic fairness, Notions of fairness, Parity based and preference based notions, Fairness and accuracy, Identifying and mitigating inherent bias in data and/or machine learning algorithms, Proper choice of representative sample, Making training data fair, Designing fairness aware classifiers, Algorithmic audit, Challenges, Audit based on user survey, Sock puppet audit, Audit based on scrapping/crawling. (12L) **Transparency and Explainability:** Black-box phenomenon and trust, Unpredictability, Explanation/Reasoning, Right to explanation, Explainability and accuracy trade off, Transparency and interpretability, DARPA XAI, ML model explainability, Linear model explainability, Nonlinear model explainability, Neural networks explainability, LIME package, SHAP values, What-if tool. (5L) **AI Ethics:** Moral issues in autonomous and intelligent systems, Narrow (or Weak) AI and General (or Strong) AI, Weaponization of AI, Moral issues in autonomous robots, Robot ethics, Moral issues in self-driving cars, Moral Machine Quiz. (5L) **Personalization:** Personalized recommendation, search and newsfeed, Intellectual isolation associated with personalization, Objective search results, Personalized advertisement, Cross-domain tracking. (3L) **Code of Ethics:** Ethical standards by international professional societies, IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, ACM Code of Ethics and Professional Conduct. (3L)
Text Books, and/or reference material	**Text Books:** 1. D J Patil, Hilary Mason, Mike Loukides, "Ethics and Data Science", O'Reilly Media, Inc.; 1st edition (July, 2018). 2. P. Singer, "Practical Ethics", Cambridge University Press, 3rd edition (February 2011) **Reference Books:** 1. Cathy O'Neil, "Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy", Crown; 1st edition (September 6, 2016).

	2. John C. Havens, "Heartificial Intelligence: Embracing Our Humanity to Maximize Machines", TarcherPerigee; (February 2, 2016). 3. Wendell Wallach, Colin Allen, "Moral Machines: Teaching Robots Right from Wrong", Oxford University Press; 1st edition (June 3, 2010). 4. Garry Kasparov, "Deep Thinking: Where Machine Intelligence Ends and Human Creativity Begins", PublicAffairs; 1st edition (May 2, 2017).

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90**	Optical Networks	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))
Basic Concepts of Computer Networks, and Algorithms	CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**

Course Outcomes	• CO1: To obtain a concept of optical networks and its advantages. • CO2: Understanding of the different optical network components. • CO3: To explore the different issues of optical networks like routing and wavelength assignment (RWA), virtual topology design, wavelength rerouting, Traffic grooming. • CO4: Understanding of the wavelength convertible network. • CO5: Comprehend the multicast routing in optical networks.
Topics Covered	**Optical Networks Fundamentals**: Optical fiber principles, Advantages of optical networks, Optical transmission system, Wavelength Division Multiplexing(WDM), Optical network architectures, Different issues in wavelength routed networks. (05) **Optical Network Components:** Couplers, Isolators & Circulators, Multiplexers & Filters, Optical Amplifiers, Optical Line Terminals (OLT), Optical Network Unit (ONU), Optical add/Drop multiplexers (OADM), reconfigurable OADMS, Optical Cross Connects (OXC), Wavelength Converters. (04) **Routing and Wavelength Assignment (RWA) algorithms**: Mathematical formulation of the RWA problem, Route Selection algorithms, Wavelength Selection algorithms, Joint wavelength-route selection algorithm. Fairness and Admission Control, Distributed Control protocols. (06L) **Wavelength Convertible Networks**: Need for Wavelength Converters, Wavelength convertible Switch Architecture, Routing in Convertible Networks, Performance Evaluation of Convertible networks, Network with Sparse Wavelength Conversion, Converter Placement Algorithm. (05L) **Wavelength Rerouting Algorithm**: Benefits of wavelength rerouting, Issues in wavelength rerouting, Lightpath Migration, Rerouting Schemes, Rerouting algorithm: Auxiliary Graph (AG) algorithm, MWPG algorithm. (04L) **Virtual Topology Design**: Physical and Virtual topology, Virtual topology design problem, Limitations on virtual topology, Mathematical formulation of the virtual topology problem, Virtual topology design heuristics, Predetermined virtual topology and lightpath routes. (05L) **Virtual Topology Reconfiguration:** Need for virtual topology reconfiguration, Virtual topology reconfiguration heuristics. (03L) **Traffic Grooming:** Basic concepts, Grooming node architecture, ILP formulation of the traffic grooming problem, Different heuristics (MST, MRU, TGCP, etc) for the traffic grooming problem. (05L)

	Optical Multicast Routing: Multicast routing problem, different types of nodes to support multicasting, Network with full splitting and sparse splitting, Multicast Tree generation algorithms. (05L)
Text Books, and/or reference material	**Text Books:** 1. WDM OPTICAL NETWORKS Concepts, Design and algorithms by C. Siva Ram Murthy and Mohan Gurusamy (PHI) 2. Optical Networks: A Practical Perspective (3rd Edition) by R. Ramaswami, K. Sivarajan, G. Sasaki (Morgan Kaufmann Publishers) **Reference Books:** 1. OPTICAL NETWORKS by Biswanath Mukherjee (TMH)

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90**	Optical and Wireless Communication Networks	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
Computer Networks		CA+ MT + ET [CA: 15%, MT: 25%, ET: 60%]					

Course Outcomes	• CO1: To understand the fundamentals of wireless networks. • CO2: To explore the 4G and LTE networks. • CO3: To learn the concepts of optical networks. • CO4: To achieve the knowledge on emerging technologies. • CO5: To understand the design of hybrid optical-wireless networks.
Topics Covered	**ACCESS NETWORKS OVERVEIW:** Access Technologies: DSL standards, Hybrid fiber coaxial Cable, Modem, WLAN / IEEE 802.11, Access methods, WiMAX / 802.16, Optical Access Networks, Passive Optical Networks: standards and Development, WDM-PON. (8) **Wireless Communication Networks:** 3G Overview, Migration path to UMTS, UMTS Basics, Air Interface, 3GPP Network Architecture, 4G features and challenges, 4G Technology path, IMS Architecture, LTE – system overview. (8) **INTERNETWORKING BETWEEN WLANs AND 3GWANs:** Internetworking-objectives and requirements, schemes to connect WLANs and 3G networks, Internetworking architecture for WLAN and GPRS, LMDS, MMDS. (6) **PASSIVE OPTICAL NETWORKS ARCHITECTURES AND PROTOCOLS:** PON Architectures, Network Dimensioning and operation, Broadband PON: architecture, protocol and Service, Bandwidth allocation. Gigabit-Capable PON. Ethernet PON Architecture, 10GEPON PMD Architecture. (10) **OPTICAL ACCESS AND HYBRID OPTICAL -WIRELESS ACCESS NETWORKS:** TDM-PON Evolution, WDM-0PON Components and Network Architectures, Hybrid TDM/WDM-PON, WDM-PON Protocols and Scheduling Algorithms, Hybrid Optical–Wireless Access Network Architecture, Radio Over fiber architectures. (10)
Text Books, and/or reference material	**Text Books:** 1. Kaveh Pahlavan and Prashant Krishnamurthy, ‘Principle of Wireless network- A Unified Approach’, Prentice Hall.

	2. Moray Rumney, 'LTE and the Evolution to 4G Wireless Design and Measurement Challenges', Agilent Technologies. 3. Leonid G. Kazovsky, Ning Cheng, Wei-Tao Shaw, David Gutierrez, Shing-Wa Wong, 'Broadband Optical Access Networks', John Wiley and Sons, New Jersey. 4. P.E. Green, Jr., 'Fiber Optic Networks', Prentice Hall, NJ. **Reference Books:** 2. G.E. Keiser, 'Optical fiber communication', McGraw Hill. 3. Andrea Goldsmith, 'Wireless Communications', Cambridge University Press. 4. R. Ramaswami, K. Sivarajan, G. Sasaki, 'Optical Networks: A Practical Perspective' (3rd Edition), (Morgan Kaufmann Publishers).

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9013	Wireless Networks & Mobile Computing	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Computer Networks		CT+EA					
Course Outcomes	**CO1:** Introduce to the basic of Wireless Networks **CO2:** Preparing the right background to take up research works in emerging wireless technologies and Internet of Things. **CO3:** Hands-on experience on Wireless Networks & Mobile Computing						

<table>
<tr><td>Topics Covered</td><td>Module 1: Basic Introduction of TCP/IP Protocol Stack & Hands-on (4 Hours)
Introduction of TCP/IP Protocol Stack, Functionalities of each and every Layers, Concept of Socket. Difference between Wireless Networks & Mobile Computing
Analysis of TCP/IP stack using Wireshark.

Module 2: Wireless LAN (WiFi & Bluetooth) (10 Hours)
Bit transmission over Wireless, Vary Much different from Wired Network
Access in Shared Medium, Difference between Wired MAC & Wireless MAC, Different Type of MACs (a) Random MAC (b) Scheduled MAC,
Examples of MAC Implementation (WiFi Protocol --802.11, Bluetooth Protocol--805.15)

Module 3: Adhoc & Delay Tolerant Network (12 Hours)
Reactive Routing, Proactive Routing, DSR Principle, AODV Principle, Location Aware Routing.
Adhoc Network, Delay Tolerant Network, Opportunistic Network Introduction, Architecture & Applications, Routing Algorithms – Epidemic, Prophet, Spray & Wait, Spray & Focus, Maxprop
Simulation Tool - ONE Simulator

Module 4: 5G Evaluation & Applications: (10 Hours)
MTC, D2D Communication, Multihop D2D, Multi-carrier D2D:Machine-type communications: Fundamental techniques for MTC – Massive MTC – Ultra-reliable low-latency MTC – Device-to-device (D2D) communications – Multi-hop D2D communications – Multi-operator D2D communication – Simulation methodology: Evaluation methodology – Calibration – New challenges in the 5G modeling.

Module 5: Emerging Technologies & Case Studies (6 Hours)
Communication using Light (LiFi/VLC) & Sound signal, Opportunists Networks for Post Disaster Management, Drone base Communication System</td></tr>
<tr><td>Text Books, and/or reference material</td><td>Text Books:
1. "Mobile Communication", by Jochen Schiller (PEARSON EDUCATION LIMITED)
2. “Wireless Networking” A kumar, D. manjunath, J. Kuri, Elsevier, 2008.
3. “Wireless Communication”, T. S. Rappaport, Pearson, latest edition.

References:
Research Papers
1. IEEE Infocom Tutorials slides by Prof. Nitin Vaidya.

Tools: Sniffer Tool (Wireshark)

1. OMNET
2. ONE
3. NS3</td></tr>
</table>

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90**	Smartphone Computing & Applications	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))
Computer Networks, Algorithms, Computer Communication	CE+EA

Course Outcomes	• CO1: Understanding the basics of how smartphones communicate and can be programmed • CO2: To have a knowledge on energy management and privacy/security related to smartphones • CO3 To understand different issues related to localization and user mobility • CO4: To explore different challenges in affective computing, activity and gesture recognition • CO5: To explore the research domain of computing using smartphones
Topics Covered	**Networking Basics:** Wireless LAN, Bluetooth, WifiDirect, NFC **Programming platforms:** Overview of different mobile programming environments, Difference with the classical programming practices, Introduction to mobile operating systems, iOS, Android, Windows, Mobile application development. **Wireless Energy Management:** Measurement of energy consumption, WiFi Power Save Mode (PSM), Constant Awake Mode (CAM), Different Sleep States, WiFi Energy management **Localization:** User location and tracking system, Cell tower localization, Spot localization, Logical location, Ambience fingerprinting, War-driving, Localization without war-driving, Indoor localization, Crowd sourcing for localization. **Context Sensing:** Context-Aware system, Automatic Image Tagging, Safety critical applications (case study: determining driver phone use), Energy-efficient Context Sensing, Contextual Ads and Mobile Apps. **Mobile affective computing:** Human Activity and Emotion Sensing, Health Apps **Activity and Gesture Recognition:** Machine Recognition of Human Activities, Mobile Phones to Write in Air, Crowdsensing based activity recognition, Personalized Gesture Recognition, Content Rating, Recognizing Human without Face Recognition, Phone-to-Phone Action Games, Interface design issues, Touchscreen, Gesture-based Input. **Mobility:** Overview of Mobility models, Automatic Transit Tracking, Mapping, Arrival Time Prediction, Augmenting Mobile 3G with WiFi, Vehicular WiFi Hotspots, Code Offload **Privacy and Security:** Authentication on Mobile Phones, Activity based Password, Finger Taps usage as Fingerprints, Location Privacy
Text Books, and/or reference material	Text Books: 1. Smart Phone and Next Generation Mobile Computing (Morgan Kaufmann Series in Networking), PeiZheng, Lionel Ni 2. Principles Of Mobile Computing, Hansmann, LotharMerk, Martin Niclous, Stober 3. Mobile Computing, Tomasz Imielinski, Springer Reference Books References: Papers from the ACM and IEEE digital libraries.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	High Performance Computing	PEL	3	0	0	3	3
Pre-Requisite: Computer architecture, OS and Networking		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					
Course Outcomes	• CO1: Provide systematic and comprehensive treatment of the hardware and the software high performance techniques involved in current day computing. • CO2: Introduce the learner to fundamental and advanced parallel algorithms through the GPU and MIC programming environments • CO3: Provide systematic and comprehensive treatment of the components in the pipeline that extract instruction level parallelism. • CO4: Provide a strong foundation on memory hierarchy design and tradeoffs in both uniprocessor and multiprocessors.						
Topics Covered	**Graphics Processing Units**: Introduction to Heterogeneous Parallel Computing, GPU architecture, Thread hierarchy,GPU Memory Hierarchy. (8) **GPGPU Programming:** Vector Addition, Matrix Multiplication algorithms. 1D, 2D, and 3D Stencil Operations. Image Processing algorithms – Image Blur, Grayscaling. Histogramming, Convolution, Scan, Reduction techniques. (8) **Many Integrated Cores:** Introduction to Many Integrated Cores. MIC, Xeon Phi architecture, Thread hierarchy. Memory Hierarchy. Memory Bandwidth and performance considerations. (8) **Xeon Phi Programming:** Vector Addition, Matrix Multiplication algorithms. 1D, 2D, and 3D Stencil Operations. Image Processing algorithms – Image Blur, Grayscaling. Histogramming, Convolution, Scan, Reduction techniques. (8) **Shared Memory Parallel Programming:** Symmetric and Distributed architectures. OpenMP Introduction. Thread creation, Parallel regions. Worksharing, Synchronization. (5) **Message Passing Interface:** MPI Introduction. Collective communication. Data grouping for communication. (5)						
Text Books, and/or reference material	**Text Books:** 5. Wen-Mei W Hwu, David B Kirk, Programming Massively Parallel Processors A Hands-on Approach, Morgann Kaufmann, 3e. 6. Rezaur Rahman, Intel Xeon Phi Coprocessor Architecture and Tools, Apress Open, 2013. 7. Barbara Chapman, Gabriele Jost, Ruud van der Pas, Using OpenMP, MIT Press, 2008.						

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

<table>
<tr><td>CSE 90XX</td><td>Wireless sensor & Adhoc networks</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2"><u>Pre-Requisite</u>: Data Communication and Computer Networks</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2"></td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the WSN node Architecture and Network Architecture
CO2:To identify the Wireless Sensor Network Platforms
CO3: Explain fundamental principles of Ad-hoc Networks
CO4: Discuss a comprehensive understanding of Ad-hoc network protocols</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Introduction to Wireless Sensor Networks (WSNs), Motivation, Performance Requirement, Diverse applications, Ad-hoc Wireless Networks Introduction, Issues in Ad-hoc Wireless Networks, Ad-hoc Wireless Internet; MAC Protocols for Ad-hoc Wireless Networks: Introduction, Issues in Designing a MAC Protocol, Design Goals of MAC Protocols, Classification of MAC protocols (4)

Wireless Sensor Network Architecture: Hardware components, Energy consumption of sensor nodes, Motes, Sensor Devices, Types of Sensors, Sensor's specification, Operating systems and execution environments, Sensor network scenarios, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts (3)

Localization and positioning: Properties of localization and positioning procedures, Possible approaches (Proximity, Trilateration and triangulation, Scene analysis), Mathematical basics for the lateration problem, Single-hop localization, Positioning in multi-hop environments (5)

Topology control: Motivation and basic ideas, Controlling topology in flat networks – Power control, Hierarchical networks by dominating sets, Hierarchical networks by clustering, Combining hierarchical topologies and power control, Adaptive node activity (5)

Routing protocols: Forwarding and routing, Energy-efficient unicast routing, Geographic and Random Routing, Clustering Algorithms in routing, Fault Tolerance in Wireless Sensor Networks, Routing Protocols for Ad-hoc Wireless Networks Introduction, Issues in Designing a Routing Protocol for Ad-hoc Wireless Networks; Classification of Routing Protocols; Table Driven Routing Protocols; On-Demand Routing Protocols, Hybrid Routing Protocols, Hierarchical Routing Protocols and Power-Aware Routing Protocols. (12)

Transport layer and Quality of Service (QoS): Coverage and deployment, Reliable data transport, Single packet delivery, Block delivery, Congestion control and rate control, Energy Management in Ad-hoc Wireless Networks, Classification of Energy Management Schemes, Battery Management Schemes, Transmission Management Schemes, System Power Management Schemes. (10)

Security in Ad-hoc Wireless Networks: Issues and Challenges in Security Provisioning, Network Security Attacks, Key Management and Secure Touting Ad-hoc Wireless Networks. (3)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:

8. H. Karl and A. Willig, Protocols and Architectures for Wireless Sensor Networks, Wiley Publishers , 2005
9. E. H. Callaway, Jr. E. H. Callaway, Wireless Sensor Networks Architecture and Protocols:, CRC Press , 2009
10. Ozan K. Tonguz and Gianguigi Ferrari: Ad-hoc Wireless Networks, John Wiley, 2007.
11. Xiuzhen Cheng, Xiao Hung, Ding-Zhu Du: Ad-hoc Wireless Networking, Kluwer Academic Publishers, 2004.</td></tr>
</table>

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 9013	Basics of IoT & Its Applications	PEL	2	1	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Computer Networks	CT+EA

Course Outcomes	CO1: Introduce to the basic of of Wireless Networks CO2: Preparing the right background to take up research works in emerging wireless technologies and Internet of Things. CO2: To introduce the scopes of using sensing, edge computing, Machine learning mechanisms in pervasive cyber physical systems. CO3: Able to understand the innovation opportunity in IoT application segments. CO4: Hands-on experience on Wireless Networks & Mobile Computing
Topics Covered	**Module 1: Introduction to IoT and Sensing** (8 Hours) Introduction to IoT, Sensing, Edge computing, Data processing, Learning. Different type of sensors, working principal of some sensors like Ultrasonic sensor, Thermal Sensors, Infrared Sensors, Pollutant Sensors, Ph, Turbidity, Dissolved oxygen sensor, Temp, water flow sensors etc. **Module 2: Sensing in IoT & Edge Computing** (6 Hours) Open source hardware, Play with Sensors using Arduino Programming, Local data processing using Raspberry Pi/Uddo Neo, Play with different Network Modules (Bluetooth, WiFi, GSM/GPRS) **Module 3: Communication in IoT** (10 Hours) Concept of TCP/IP protocol Stack, 802.11 Protocol (WiFi Network), LoRa Network, Visible light Communication, Socket Programming, Wireshark Tool. **Module 4: IoT Protocols (6 Hours)** QUIC Protocol, CoAP, MQTT

	Module 5: Case Study (12 Hours) Case Study 1: **(activity Identification)** Human Activity using Ultra sonic Sensors/Thermal Sensors, Case Study 2: **(Environment Monitoring)** Pollution Monitoring and Forecasting in Indoor and Outdoor, Case Study 3: **(Road Transportation System)** Important PoIs using GPS trails, Road Speed Identification, Street Light Monitoring Case Study 4: **(Challenged Networks)** offline Crisis Mapper Design Case Study 4: **(Agriculture)** offline Crisis Mapper Design using ChatBot
Text Books, and/or reference material	**Text Books** 1. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press) 2. "Internet of Things: A Hands-on Approach", by Arshdeep Bahga and Vijay Madisetti (Universities Press)

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Cloud Computing	PCR	3	0	0	3	3
Pre-requisites:		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET [CA: 15%, MT: 25%, ET: 60%]					

Course Objective	At the completion of this course students will be able to: CO1: The fundamental ideas behind Cloud Computing, the evolution of the paradigm, its applicability; benefits, as well as current and future challenges. CO2: The basic ideas and principles in data center design; cloud management techniques and cloud software deployment considerations. CO3: Understand the concept of virtualization and how this has enabled the development of Cloud Computing. CO4: Understand scaling, Storage model, Data processing service and cloud security.
Topics Covered	UNIT-I: Cloud Computing Overview: Origins of Cloud computing – Cloud components - Essential characteristics – On-demand self-service, Broad network access, Location independent resource pooling ,Rapid elasticity , Measured service, Comparing cloud providers with traditional IT service providers, Roots of cloud computing, Cloud Architectural influences – High-performance computing, Utility and Enterprise grid computing, Cloud scenarios – Benefits: scalability ,simplicity ,vendors ,security, Limitations – Sensitive information - Application development- security level of third party - security benefits, Regularity issues: Government policies. (8L) UNIT-II: Cloud Architecture- Layers and Models Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS), features of PaaS and benefits, Infrastructure as a Service (IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Cloud deployment model: Public clouds – Private clouds – Community clouds - Hybrid clouds - Advantages of Cloud computing. (8L)

	UNIT-III: Management of Cloud Services: Reliability, availability and security of services deployed from the cloud. Performance and scalability of services, tools and technologies used to manage cloud services deployment; Cloud Economics: Cloud Computing infrastructures available for implementing cloud based services. Economics of choosing a Cloud platform for an organization, based on application requirements, economic constraints and business needs. (10L) UNIT-IV: Defining the Clouds for Enterprise: Storage as a service, Database as a service, Process as a service, Information as a service, Integration as a service and Testing as a service. Scaling cloud infrastructure - Capacity Planning, Cloud Scale. Layered Data Processing Approach – Cloud, Fog and Edge. (6L) UNIT-V: Cloud Storage - Global storage management locations, scalability, operational efficiency. Global storage distribution; terabytes to petabytes and greater. Policy based information management; metadata attitudes; file systems or object storage. (4L) UNIT-VI: Cloud Security: Confidentiality, privacy, integrity, authentication, non-repudiation, availability, access control, defence in depth, least privilege, how these concepts apply in the cloud, what these concepts mean and their importance in PaaS, IaaS and SaaS. e.g. User authentication in the cloud; Cryptographic Systems- Symmetric cryptography, stream ciphers, block ciphers, modes of operation, public-key cryptography, hashing, digital signatures, public-key infrastructures, key management, X.509 certificates, OpenSSL. Multi-tenancy issues, Virtualized System Specific Issues. (6L)
Text Books, and/or reference material	Text Books: Cloud computing a practical approach - Anthony T.Velte , Toby J. Velte Robert Elsenpeter, TATA McGraw- Hill. Cloud Computing (Principles and Paradigms), Edited by Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc

<table>
<tr><th colspan="9">Department of Computer Science & Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CSE 90XX</td><td>Data Warehousing</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3"><u>Pre-Requisite</u>: Database Management System</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3"></td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To introduce basic principles, concepts and applications of data warehousing
CO2: To introduce mathematical statistics foundations in data warehousing
CO3: Understand the design of data warehouse with dimensional modeling
CO4: Apply OLAP operations and its advanced applications</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Moving toward the Information Age, Evolution of Information Technology, Different types of data (Database Data, Data Warehouses, Transactional Data, Other Kinds of Data), Database Systems and Data Warehouses, Data warehousing applications (2)

Getting to Know Your Data: Data Objects and Attribute Types (Nominal Attributes, Binary Attributes, Ordinal Attributes, Numeric Attributes, Discrete versus Continuous Attributes), Basic Statistical Descriptions of Data (Measuring the Central Tendency: Mean, Median, and Mode, Measuring the Dispersion of Data: Range, Quar tiles, Variance, Standard Deviation, and Inter quartile Range), Measuring Data Similarity and Dissimilarity (Data Matrix versus Dissimilarity Matrix, Proximity Measures for Nominal Attributes, Proximity Measures for Binary Attributes, Dissimilarity of Numeric Data: Minkowski</td></tr>
</table>

	Distance, Proximity Measures for Ordinal Attributes, Dissimilarity for Attributes of Mixed Types, Cosine Similarity), **(6)** **Data Preprocessing**: Data Quality, Major Tasks in Data Preprocessing, Data Cleaning (Missing Values, Noisy Data, Data Cleaning as a Process), Data Integration (Entity Identification Problem, Redundancy and Correlation Analysis, Tuple Duplication, Data Value Conflict Detection and Resolution), Data Reduction (Attribute Subset Selection, Regression and Log-Linear Models: Parametric Data Reduction**),** Histograms, Data Transformation and Data Discretization (Data Transformation Strategies Overview, Data Transformation by Normalization, Discretization by Binning) **(6)** **Data Warehouse:** What Is a Data Warehouse? Differences between Operational Database Systems and Data Warehouses, But, Why Have a Separate Data Warehouse?, Data Warehousing: A Multi-tiered Architecture, Data Warehouse Models: Enterprise Warehouse, Data Mart, and Virtual Warehouse, Extraction, Transformation, and Loading, Metadata Repository, Data Warehouse Design and Usage : Data Warehouse Design Process, Data Warehouse Usage for Information Processing, A Business Analysis Framework for Data Warehouse Design **(6)** **Data Warehouse Modeling:** Data Cube and OLAP, Data Cube: A Multidimensional Data Model, Stars, Snowflakes, and Fact Constellations: Schemas for Multidimensional Data Models, Dimensions: The Role of Concept Hierarchies, Measures: Their Categorization and Computation **(4)** **OLAP Operations:** Typical operations in OLAP, A Starnet Query Model for Querying Multidimensional Databases, From Online Analytical Processing to Multidimensional Data Mining, Indexing OLAP Data: Bitmap Index and Join Index, Efficient Processing of OLAP Queries, OLAP Server Architectures: ROLAP versus MOLAP versus HOLAP, Data Generalization by Attribute-Oriented Induction: Attribute-Oriented Induction for Data Characterization, Efficient Implementation of Attribute-Oriented Induction, Attribute-Oriented Induction for Class Comparisons **(6)** **Data Cube Technology:** Data Cube Computation: Preliminary Concepts (Cube Materialization: Full Cube, Iceberg Cube, Closed Cube, and Cube Shell, General Strategies for Data Cube Computation), Data Cube Computation Methods: Multiway Array Aggregation for Full Cube Computation, BUC: Computing Iceberg Cubes from the Apex Cuboid Downward, Star-Cubing: Computing Iceberg Cubes Using a Dynamic Star-Tree Structure, Pre-computing Shell Fragments for Fast High-Dimensional OLAP, Processing Advanced Kinds of Queries by Exploring Cube Technology, Sampling Cubes: OLAP-Based Mining on Sampling Data, Ranking Cubes: Efficient Computation of Top-k Querie **(8)** **Multidimensional Data Analysis in Cube Space:** Prediction Cubes: Prediction Mining in Cube Space, Multifeature Cubes: Complex Aggregation at Multiple Granularities, Exception-Based, Discovery-Driven Cube Space Exploration **(4)**
Text Books, and/or reference material	**Text Books:** 1. Building The Data Warehouse, W. H. Inmon, Wiley Computer Publication, 3rd Edition. 2. Data Modeling Techniques for Data Warehousing, Chuck Ballard, Dirk Herreman, Don Schau, Rhonda Bell, Eunsaeng Kim, Ann Valencic, IBM Red Book, February 1998 3. The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling, Ralph Kimball & Margy Ross, Wiley Computer Publication, 2nd Edition

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Data Warehousing	PEL	3	0	0	3	3

Pre-Requisite: Database Management System		Course Assessment methods (Continuous (CT) and end assessment (EA))
		CT+EA
Course Outcomes	• CO1: To introduce students to the basic concepts and techniques of Data Mining. • CO2: To introduce a wide range of clustering, estimation, prediction, and classification algorithms. • CO3: introduce mathematical statistics foundations of the Data Mining Algorithms • CO4: Apply data mining techniques in inter-disciplinary areas	
Topics Covered	**Introduction**: Data Mining as the Evolution of Information Technology, What Kinds of Data Can Be Mined? What Kinds of Patterns Can Be Mined? Technologies Used in data mining, Different Applications in data mining, Major Issues in Data Mining, Data Mining and Society, Basic concepts on Data Warehousing (2) **Mining Frequent Patterns, Associations, and Correlations:** Basic Concepts - Frequent Itemsets, Closed Itemsets, and Association Rule, Apriori Algorithm: Finding Frequent Itemsets by Confined Candidate Generation, Generating Association Rules from Frequent Itemsets, Improving the Efficiency of Apriori, A Pattern-Growth Approach for Mining Frequent Itemsets, Mining Frequent Itemsets using Vertical Data Format, Mining Closed and Max Patterns, Pattern Evaluation Methods (6) **Classification:** Basic Concepts (What Is Classification?, General Approach to Classification**),** Decision Tree Induction, Bayes Classification Methods, Rule-Based Classification, Metrics for Evaluating Classifier Performance, Techniques to Improve Classification Accuracy (8) **Advanced classification methods:** Bayesian Belief Networks, Classification by Backpropagation, Support Vector Machines, Lazy Learners (k-Nearest-Neighbor Classifier), Multiclass Classification, Semi-Supervised Classification, Basic concepts of Active Learning and Transfer Learning (8) **Cluster Analysis:** Basic Concepts and Methods, Partitioning Methods (k-Means: A Centroid-Based Technique, k-Medoids: A Representative Object-Based Technique), Hierarchical Methods (Agglomerative vs. Divisive Hierarchical Clustering, Distance Measures in Algorithmic Methods, BIRCH: Multiphase Hierarchical Clustering Using Clustering Feature Trees), Density-Based Methods (DBSCAN: Density-Based Clustering Based on Connected Regions with High Density), Grid-Based Methods (CLIQUE: An Apriori-like Subspace Clustering Method), Evaluation of Clustering (8) **Advanced Cluster Analysis:** Probabilistic Model-Based Clustering (Fuzzy Clusters), Clustering High-Dimensional Data (Problems, Challenges, and Major Methodologies), Clustering Graph and Network Data (Applications and Challenges, Similarity Measures, Graph Clustering Methods), Clustering with Constraints (6) **Outlier Detection:** Outliers and Outlier Analysis, Types of Outliers, Challenges of Outlier Detection, Outlier Detection Methods (Supervised, Semi-Supervised, and Unsupervised Methods, Statistical Methods, Proximity-Based Methods, Clustering-Based Approaches, Classification-Based Approaches) **(4)**	
Text Books, and/or reference material	**Text Books:** 4. Data Mining Concepts and Techniques : Jiawei Han, Micheline Kamber and Jian Pei, Morgan Kaufmann Publishers, Elsevier, USA. 5. Mehmed Kantardzic, “Data Mining Concepts, Methods and Algorithms”, John Wiley and Sons, USA, 2003.	

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

<table>
<tr><td>CSE 90XX</td><td>Big Data Modelling and Management</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-Requisite: Database Management System</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3"></td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO2: Understand the necessity of Big Data Infrastructure Plan in Information System Design
• CO1: Recognize different types of data elements – structural issues, characterization issues, modelling issues
• CO3: Identify the frequent data operations required for various types of data
• CO4: Apply techniques to handle streaming data</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Big data attributes and Definitions, Data Variety – Structured, Semi-structured and Unstructured, Defining Big Data from 3Vs to 3²Vs - Data Domain, Business Intelligent (BI) Domain, Statistics Domain, Introduction of big data platforms: Hadoop, HDFS, MapReduce, Spark, Google File System (GFS) and HDFS. (4)

Database Techniques for Big Data: Big data management - Data ingestion, Data storage, Data quality, Data operations, Data scalability and security; Big data management services - Data cleansing, Data integration; Storage models - Block-based storage, File-based storage, Object-based storage; Data Models - Navigational Data Models, Relational Data Models, XML, Canonical Data Model, NoSQL Movement, NoSQL Solutions for Big Data Management. (6)

NoSQL Data Models: Key-Value Stores, Column-Based Stores, Graph-Based Stores, Document-Based Stores. (6)

Operation On NoSQL Databases: CRUD operations – Creating, Updating, Accessing and Deleting Data; Query – Non-DBMS Vs DBMS Approaches, Declarative Query Language (DQL), Hive Query Language (HQL), Cassandra Query Language (CQL), Spark SQL, Query for Document Store data, MapReduce functionality; Transaction Management – Isolation Levels and Isolation Strategies, BASE Theorem, CAP Theorem. (8)

Modelling Streaming Data: Data stream and data model versus data format, Use cases of stream processing, Data streaming systems - Data harvesting, Data processing, Data analytics; Importance and implications of streaming data, streaming data solutions, Exploring streaming sensor data, Analyzing the streaming data. (4)

Resource Management in Big Data Processing Systems: Types of Resource Management – CPU, Storage, Network, Big Data Processing Systems and Platforms, Big data and Cloud Resources - Single-Resource Management, Multi-resource Management. (4)

System Optimization for Big Data Processing: Basic Framework of the Hadoop Ecosystem, Parallel Computation Framework: MapReduce; Job Scheduling of Hadoop, Performance Optimization of HDFS, Performance Optimization of HBase, Performance Enhancement of Hadoop System. (4)

Security and Privacy in Big Data: Secure Queries Over Encrypted Big Data - Threat Model and Attack Model, Secure Query Scheme in Clouds, Security Definition of Index-Based Secure Query Techniques, Implementations of Index-Based Secure Query Techniques; Privacy on Correlated Big Data (4)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
6. Big Data Principles and Paradigms, Rajkumar Buyya; Rodrigo N Calheiros; Amir Vahid Dastjerdi, Elsevier/Morgan Kaufmann, Cambridge, MA.
7. Hands-On Big Data Modelling, James Lee, Tao Wei, Suresh Kumar Mukhiya, Packt Publishing. ISBN: 9781788620901.</td></tr>
</table>

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90X5	Business Process Modelling & Analysis	PEL	3	0	0	3	3
Pre-Requisite: Basic Knowledge of Unified Modelling Language		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• CO1: Learn the shared language and notations that are used by Information Technology (IT) specialist to communicate with business stakeholders. • CO2: To obtain a comprehensive idea to Manage, analyze, design, improve and reengineer business processes in industry setting scenarios. • CO3: Understand the core concepts of business processes and their components and to apply process analysis concepts and techniques. • CO4: Understand how the business process model may interface with business process management software suites (BPMS), service-oriented architecture platforms and other modern IT infrastructure platform software
Topics Covered	**Introduction to Business Process Management:** Ingredients of a Business Process, the business process Lifecycle; Process Identification - Key Processes, Designing a Process Architecture, Construct Case/Function Matrices, Simple Case studies. (2) **Process Modelling Foundation:** Business Process Modelling and Notations (BPMN) core concepts, Branching and Merging, Exclusive Decisions, Parallel Execution, Inclusive Decisions, Information Artefacts. (4) **Advanced Process Modelling**: Process Decomposition, Process Reuse, Process Rework and Repetition; Handling Events, Handling Exceptions, Processes and Business Rules, Process Choreographies and orchestration. (4) **Process Discovery:** The Setting of Process Discovery, Discovery Methods - Evidence-Based Discovery, Interview-Based Discovery, Workshop-Based Discovery, Strengths and Limitations; Process Modelling Method - Identify the Process Boundaries, Activities, Events, Resources Control Flow and Additional Elements, Process Model Quality Assurance (6) **Process Analysis:** Qualitative analysis - Value-Added Analysis, Root Cause Analysis Cause–Effect Diagram, Why–Why Diagram, Quantitative Analysis - Performance Measures, Flow Analysis, Calculating Cycle Time, Queueing Theory, Process simulation. (6) **Process Based analysis:** Introduction to Analytical Hierarchy Process and Analytical Network Process. (3) **Process Redesign:** The Essence of Process Redesign, Heuristic Process Redesign, Business Process Operation Heuristics, Business Process Behaviour Heuristics, Organization Heuristics, Information Heuristics Deriving business Process from a Product Data Model (5) **Process Automation:** Automating Business Processes - BPMS and Architecture of BPMS; Workload Reduction, Flexible System Integration Execution Transparency, Rule Enforcement, (5) **Process Intelligence:** Process Execution and Event Logs, Automatic Process Discovery - The α-Algorithm, Robust Process Discovery; Performance Analysis - Time Measurement, Cost Measurement; Quality Measurement, Flexibility Measurement; Conformance Checking - Conformance of Control Flow, Data and Resources (5)

Text Books, and/or reference material	Text Books: 1. Fundamentals of Business Process Management, Authors: Marlon Dumas Marcello La Rosa, Jan Mendling, Hajo A Reijers, Springer Heidelberg New York, ISBN 978-3-642-33142-8 2. BUSINESS PROCESS MODEL AND NOTATION SPECIFICATION VERSION 2.0 [https://www.omg.org/spec/BPMN/2.0/About-BPMN/] 3. Business Process Management For Dummies®, 4th IBM Limited Edition Published by John Wiley & Sons, Inc..

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90XX	Complex Network Theory	PEL	3	1	0	4	4
Pre-requisites: Probability & Statistics, Algorithms		Course Assessment methods (Continuous (CT) and end assessment (EA))					
CSE 1001		CT+EA					
Course Outcomes	• CO1: To explain why a general graph theory course fails to deal with structure and dynamics of large-scale real-world networks • CO2: To introduce different parameters for understanding complex network • CO3: To understand and analyses the structure and dynamics of complex networks • CO4: To understand different growth models • CO5: To study different processes and applications on complex network						
Topics Covered	**Basic Concepts related to Social Networks:** Small world effect, transitivity and clustering, degree distribution, scale free networks, maximum degree; network resilience; mixing patterns; degree correlations; community structures; network navigation. (6) Centrality measures, Node Popularity, Page Rank algorithm, Spectral Graph Theory. (6) **Community Structure Analysis-** Basic concepts of network communities, various community finding approaches like Girvan-Newman Algorithm, Spectral Bisection Algorithm, Radicchi Edge Clustering Algorithm (for binary as well as weighted graphs), Wu-Hubermann Algorithm, and Random Walk based Algorithm. (6) **Random Graphs-**Poisson random graphs, generating functions, emergence of giant component, power-law degree distribution, bipartite graph. (10) **Random walk on Graphs-** Limitations of page rank, page rank++, HITS, Chinese Whispers, Affinity Propagation algorithm. (6) **Processes taking place on Networks-** Percolation theory and network resilience, Epidemiological processes. (8)						

Text Books, and/or reference material	**TEXT Books:** 1. Guido Caldarelli, Scale-Free Networks, Oxford University Press, Oxford (2007) 2. S. N. Dorogovtsev and J. F. F. Mendes, Evolution of Networks, Oxford University Press, Oxford (2003) **REFERENCE Books:** 1. M. E. J. Newman, The structure and function of complex networks, SIAM Review 45, 167-256 (2003). 2. R. Albert and A. L. Barabasi Statistical mechanics of complex networks. Rev. Mod. Phys., Vol. 74, No. 1, January 2002.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS9021	Soft Computing	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Discrete Mathematics, Probability and Statistics, Optimization		CT+EA					
Course Outcomes	CO: Conceptualize and parameterize various problems to be solved through basic soft computing techniques. CO: Apply fuzzy logic and reasoning to handle uncertainty to solve various engineering problems. CO: Analyze various neural network architectures and learning rules CO: Apply genetic algorithms to combinatorial optimization problems. CO: Identify, select and implement a suitable soft computing technique to solve the real life problem CO: Use various tools to solve soft computing problems.						

Topics Covered	**Introduction to Soft Computing:** Characteristics of soft computing, soft computing vs. hard computing, soft computing constituents, hybrid computing, some applications of soft computing techniques. 3L **Fuzzy Logic**: Crisp Sets vs. fuzzy sets, membership functions, Characteristics of fuzzy sets, Operations on fuzzy sets, Fuzzy Variable, Fuzzy Extension principles, Fuzzy and Crisp relations, Operations on Fuzzy Relations, Composition and Decomposition of Fuzzy Relations. Fuzzy Measures and Fuzzy Arithmetic, Fuzzification and Defuzzification, Fuzzy System, Fuzzy Inference /Approximate reasoning, fuzzy decision making.Applications: Pattern Recognition, Image Processing and Controller. 12L **Neural Networks:** Introduction to Neural Networks, Biological Neural Networks, McCulloch Pitt model, Neuron and its model, Activation functions, Learning rules, Supervised Learning: Single Layer and Multi-layer perceptron, Delta learning rule, Back Propagation algorithm, Unsupervised Learning: Hebbian Learning, Competitive learning, Self-organizing Maps. 12L **Evolutionary Computing and Genetic Algorithm:**Optimization and Some Traditional Methods.Evolutionary Computing, Basic concepts and working principle of simple GA (SGA), Genetic Operators: Selection, Crossover and Mutation, Algorithm and flow chart of SGA, Encoding & Decoding, Population Initialization, Objective/fitness Function, Applications: TSP. Multi-objective Genetic Algorithm (MOGA): Multi-objective optimization problems (MOOPs), Conflicting objectives, Non-Pareto and Pareto-based approaches to solve multi-objective optimization problems, Objective space and variable space, Domination, Pareto front, Pareto Set, NSGA-II: Non-domination Sorting, Crowding distance operator. 12L **Hybrid Systems**: Integration of neural networks, fuzzy logic and genetic algorithms. 3L **Suggested Simulation/Experiments** using Matlab/Python Lib: Study of neural network toolbox and fuzzy logic toolbox, Simple implementation of Artificial Neural Network, genetic Algorithm and Fuzzy Logic.
Text Books, and/or reference material	Text Books: 1. S. Rajsekharan and VijayalakshmiPai, "Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Applications", Prentice Hall of India. 2. S.N. Sivanandam& S.N. Deepa, Principles of Soft Computing, Wiley Publications, 2nd Edition, 2011. 3. Timothy J. Ross, "Fuzzy Logic with Engineering Applications". 4. K. Deb, Multi-objective Optimization using Evolutionary Algorithms, Wiley India. Reference Books: 5. George J Klir, Bo Yuan, Fuzzy sets & Fuzzy Logic, Theory & Applications, PHI Publication, 1st Edition, 2009. 6. Neuro-Fuzzy Systems, Chin Teng Lin, C. S. George Lee, PHI. 7. Fuzzy Logic: A Pratical approach, F. Martin, Mc neill, and Ellen Thro, AP Professional, 2000. 8. An Introduction to Genetic Algorithms, Melanie Mitchell, MIT Press, 2000. 9. Neuro-Fuzzy and soft Computing, J.-S. R. Jang, C.-T. Sun, and E. Mizutani, PHI Learning, 2009. 10. Neural Networks and Learning Machines, (3rd Edn.), Simon Haykin, PHI. 11. Fuzzy Logic with Engineering Applications (3rd Edn.), Timothy J. Ross, Willey, 2010 12. Foundations of Neural Networks, Fuzzy Systems, and Knowldge Engineering, Nikola K. Kasabov, MIT Press, 1998.,

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS 90XX</td><td>Pattern Recognition (G. Sarker)</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="2">Artificial Intelligence</td><td colspan="6">CE+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Idea about Pattern and Pattern Class, Design of a Pattern Recognition System
• CO2: Idea of Instar , Outstar, Groups of Instar and Outstar, Different types of Memories.
• CO3: Concept of Feedforward, Feedback and Competitive Learning Network
• CO4: Concept of Complex PR Tasks: RBF, RBF Network for Pattern Classification
• CO5 : Idea of Temporal Pattern Recognition: Concepts</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1. Pattern and Pattern Class: Design of a Pattern Recognition System, Syntactic and Decision Theoretic Approach, Bayesian Decision Theory, Continuous Features, Error, Risk and Loss
2. Parametric and Non Parametric Methods: Histogram Method – Kernel Based Methods – K - Nearest Neighbour Method -- Probabilistic Neural Network base on Parzon Window.
3. Basics of ANN : Instar , Outstar, Groups of Instar and Outstar, Different types of Memories.
4. Pattern Recognition Tasks and Pattern Recognition Problems: Different PR Tasks by FF, FB and Competitive Learning Network, Pattern Clustering, Feature Mapping Problem, Different Feature Mapping Network, Self Organizing Network.
5. FF ANN: FF ANN: Pattern Association Network, Hebb's Law, Pattern Classification Network.
6. Single and Multilayer Network: Gradient Descent Procedure, Newton's Algorithm, Fixed Increment Learning, Variable Increment Learning, Support Vector Machine(SVM), Multilayer Neural Networks, Unsupervised Learning.
7. FB ANN: Pattern Association, Pattern Storage, Pattern Environment Storage, Auto association , Hopfield Network, Capacity and Energy of a Hopfield Network, State Transition Diagram, Stochastic Network and Boltzmann Machine.
8. Competitive Learning Network: Pattern Storage, Pattern Clustering Network, Minimal Learning, Malsburg Learning and Leaky Learning
9. Complex PR Tasks: RBF, RBF Network for Pattern Classification, Advantages of RBF over MLFF ANN, CPN Network
10. Temporal Pattern Recognition: Concepts, Problems in temporal sequence, Architecture for temporal PR Tasks, Avalanche Structure, Jordon Network, Fully Connected Recurrent Network, Difference between Avalanche Network and Jordon Network.</td></tr>
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<table>
<tr><td colspan="8">Department of Computer Science and Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
</table>

<table>
<tr><td>CSE 90**</td><td colspan="2">Biomedical Signal and Image Processing</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="3">Linear algebra, Calculus, Probability and statistics, Signal Processing.</td><td colspan="6">CE+EA</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="7">CO1: Understanding the biomedical signals and images and their characteristics.
CO2: To have a knowledge on the artifacts and noise present the biomedical signals and images.
CO3 To understand different issues to be handled for processing and enhancing the biomedical signals and images for proper analysis.
CO4: To understand different mathematical and transformation techniques for processing and enhancing biomedical signals and images
CO5: To explore the research domain of biomedical signal and image processing.</td></tr>
<tr><td colspan="2">Topics Covered</td><td colspan="7">The nature biomedical signals and images: The action potential of a cardiac myocyte and neuron, electroneurogram (ENG), electrocardiogram (ECG), electroencephalogram (EEG), electrogastrogram (EGG); phonocardiogram (PCG); speech signal; the vibromyogram (VMG); vibroarthrogram (VAG);
Imaging Modalities: ultrasound, X-ray, CT, MRI, PET, and SPECT. (6)
Fundamentals of Signal and Image Processing:
Data Acquisition: Sampling in time, aliasing, interpolation, and quantization.
Transform-domain analysis of signals and systems:
Laplace Transform and its Applications, Z-transform and its applications.
Linear Shift Invariant (LSI) Systems, Impulse Response, Transfer functions, Stability, Poles and Zeros.
DTFT: The discrete-time Fourier transform and its properties. Signal spectra.
DFT: The discrete Fourier transform and its properties, the fast Fourier transform (FFT)
Extension of DFT for 2D image signals, Wavelet Transform. (14)
Fundamental Concepts of Filtering:
Linear shift-invariant filters, IIR and FIR filters.
Time-domain Filters: Synchronized averaging, MA filters, various specifications of a filter).
Frequency-domain Filters: Butterworth lowpass filters, notch and comb filters.
Other filters: Order-statistic filters, Adaptive Filters, Applications of filtering for biomedical signals. (6)
Probability and Random Signals:
Random variables and probability density functions (PDFs), Techniques for estimating PDFs from real data, Random signals, Time averages, ensemble averages, autocorrelation functions, cross-correlation functions, Random signals and linear systems, power spectra, cross spectra, Wiener filters, Principal component analysis (PCA) and independent component analysis (ICA) for filtering. (8)
Biomedical Image Processing:
Medical Image enhancement: Gray scale transform, histogram transformation, unsharp masking, adaptive contrast enhancement, image denoising.
Medical Image Segmentation: Between class variance, Entropy-based, Clustering-based segmentation. Some recently proposed segmentation techniques for biomedical images.
Medical Image Registration: Rigid image registration, non-rigid image registration. (8)</td></tr>
<tr><td colspan="2">Text Books, and/or reference material</td><td colspan="7">Text Books:<ol start="11">
R. M. Rangayyan, Biomedical Signal Analysis, 2nd edition, Wily, 2015.
R. M. Rangayyan, Biomedical Image Analysis, CRC Press, 2005
K. Najarian and Robert Splinter, Biomedical Signal and Image Processing, 2nd edition, CRC Press, 2012.</td></tr>
</table>

	Reference Books: 3. John M. Semmlow, Biosignal and Biomedical Image Processing, Marcel Dekker, Inc., 2004. 4. R. C. Ganzalez and R. E. Woods, Digital Image Processing, 4th edition, Pearson, 2018. 5. J. S. Suri, D. L. Wilson, and S. Laxminarayan, Handbook of Biomedical Image Analysis, Vol. 1 and Vol. 2, Kluwer Academic, 2005.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90**	Introduction to Cognitive Computing	PEL	3(42)	0	0	3(42)	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Basic Concepts of AI and Information Processing.		CE+EA					
Course Outcomes	• CO1: The philosophical approach of working principle brain and mind; • CO2: Cognitive approach towards Vision and Attention. • CO3: Cognitive approach towards Memory, Language Processing. • CO4: Cognitive Architecture and Basics of Neuroscience.						
Topics Covered	• The Cognitive Revolution, Part 1 (2 Lectures) • The Cognitive Revolution, Part 2 (Philosophical issues, neuropsychological perspective) (2 Lectures) • Working Principle of the Brain(2) • Memory- Memory models: Episodic memory, Sensory memory, Short term memory, Long term memory, Explicit & Episodic Memory, Implicit Memory, Memory Accuracy, Nonverbal Memory, Semantic Memory knowledge) & Concepts (8) • Attention and Perception, Part 1 (role of brain) (Review of different approaches) (5) • Attention and Perception, Part 2 (Automaticity; Attention odds & ends) (5) • Cognitive approach to vision and pattern recognition: Template matching theory, Feature detection theory, Computational theory of vision, Feature integration theory (4) • Cognition architecture of reasoning: ACT* model, Spread of activation theory, General problem solver model, SOAR model (3) • Problem Solving(2) • Cognitive Load and its measurement (2) • Language and cognition: language formation and the brain, Word recognition, Surface level structures, Word and sentence production, Cognitive linguistic issues (3) • Introduction to Neuroscience - Looking into the Brain(4)						
Text Books, and/or reference material	Text Books: 14. Cognitive Science-An Introduction to the Study of Mind, Jay Friedenberg, Gordon Silverman, SAGE 15. Cognition, Brain and Consciousness- Introduction to Cognitive Neuroscience, Bernard J. Baars, Nicole M Gage, Elsevier						

	16. The MIT Encyclopedia of the Cognitive Sciences edited by Robert A. Wilson and Frank C. Keil

Department of Computer Science & Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS90XX	Speech Processing	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Discrete Mathematics, Probability and Statistics, Linear Algebra, Programming		CT+EA					
Course Outcomes	CO: Understand the basics of speech modelling, recognition, and synthesis. CO: More rapidly develop software, especially using skills in scripting and in the customization and combination of existing tools. CO: Comfortably use basic machine learning concepts and techniques for speech processing CO: Apply knowledge of Language and of English to improve everyday written and spoken communication, including computer-mediated communication, personally and for groups, organizations, and society.						
Topics Covered	**Basic Concepts:** Speech Fundamentals: Articulatory Phonetics – Production and Classification of Speech Sounds; Acoustic Phonetics – acoustics of speech production; Review of Digital Signal Processing concepts; Short-Time Fourier Transform, Filter-Bank and LPC Methods. (10 classes) **Speech Analysis:** Features, Feature Extraction and Pattern Comparison Techniques: Speech distortion measures – mathematical and perceptual – Log Spectral Distance, Cepstral Distances, Weighted Cepstral Distances and Filtering, Likelihood Distortions, Spectral Distortion using a Warped Frequency Scale, LPC, PLP and MFCC Coefficients, Time Alignment and Normalization – Dynamic Time Warping, Multiple Time – Alignment Paths. (10 classes) **Speech Modeling:** Hidden Markov Models: Markov Processes, HMMs – Evaluation, Optimal State Sequence – Viterbi Search, Baum-Welch Parameter Re-estimation, Implementation issues. (5 classes) **Speech Recognition:** Large Vocabulary Continuous Speech Recognition: Architecture of a large vocabulary continuous speech recognition system – acoustics and language models – ngrams, context dependent sub-word units; Applications and present status. (7 classes) **Speech Synthesis:** Text-to-Speech Synthesis: Concatenative and waveform synthesis methods, subword units for TTS, intelligibility and naturalness – role of prosody, Applications and present status. (8 classes)						
Text Books, and/or reference material	**TEXT BOOKS** 1.Lawrence Rabinerand Biing-Hwang Juang, "Fundamentals of Speech Recognition", Pearson Education, 2003.						

	2.Daniel Jurafsky and James H Martin, "Speech and Language Processing – An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition", Pearson Education. **REFERENCES** 1.Steven W. Smith, "The Scientist and Engineer's Guide to Digital Signal Processing", California Technical Publishing. 2.Thomas F Quatieri, "Discrete-Time Speech Signal Processing – Principles and Practice", Pearson Education. 3.Claudio Becchetti and Lucio Prina Ricotti, "Speech Recognition", John Wiley and Sons, 1999. 4.Ben gold and Nelson Morgan, "Speech and audio signal processing", processing and perception of speech and music, Wiley- India Edition, 2006 Edition. 5.Frederick Jelinek, "Statistical Methods of Speech Recognition", MIT Press.

Department of Computer Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90XX	Knowledge Based System Engineering	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Artificial Intelligence		CE+EA					

Course Outcomes	• CO1: Idea about Knowledge Representation and knowledge-base construction • CO2: Idea of knowledge creation, storage, acquisition, search and organization. • CO3: Concept of problem identification and solution through Reasoning, decision trees, rule based systems etc. • CO4: Concept of Expert Systems, knowledge-based decision support and detection systems. • CO5: Ability to apply knowledge to solve engineering problems.
Topics Covered	**UNIT I Fundamentals of knowledge and its types:** Concept of knowledge, types of knowledge, declarative knowledge, procedural knowledge, inheritable knowledge, inferential knowledge, relational knowledge, heuristic knowledge, commonsense knowledge, explicit knowledge, tacit knowledge, expert knowledge, uncertain knowledge. Need for maintaining Knowledge base and its management and engineering, Valuation of Intellectual Capital, Intellectual Capital: Human vs. Structural Capital. The knowledge Life Cycle and its models. (5) **UNIT II Knowledge Representation and understanding:** Data, information and knowledge relation, Knowledge vs Intelligence, the need of knowledge representation, knowledge representation using rules, procedural vs. declarative knowledge. Levels of knowledge representation, granularity of knowledge representation, granularity vs. size of knowledge-base, techniques of knowledge representation, frames, frame-based reasoning, rule-based reasoning, case-based reasoning, frame based knowledge representation, forward vs. backward reasoning.

	(10 L) **UNITIII Knowledge Creation, Storage And Acquisition:** Nonaka's Model of Knowledge Creation & Transformation, Knowledge Architecture, knowledge acquisition, indexing techniques, fuzzy distance calculation, issues in knowledge acquisition, requirements of knowledge acquisition techniques, issues in knowledge acquisition in organization, knowledge organization and management, consistency of knowledge representation during creation, storage and acquisition. (8 L) **UNIT IV Knowledge Search:** Dumb search, Heuristic search in Knowledge-Based Systems, depth-first search, breadth-first search, heuristic search, greedy search, A* algorithms, hill climbing. (3 L) **UNIT IV Knowledge organization in knowledge base:** Need of organizing knowledge, techniques of knowledge organization, Application of object-oriented and case-based knowledge organizations with case studies. (4L) **UNIT V Knowledge reuse:** Knowledge reuse technique in the designing of expert systems, components of knowledge engineering based problem solution methodology: problem representation and derivation of solution through reasoning, rule-based systems, case based reasoning (CBR), decision tree etc., weaknesses of rule based systems. Re-Using Past History Explicitly as Knowledge in CBR systems, some Case studies of CBR, Successful vs failed cases, Indexing the case library: Advantages and Disadvantages of Case based systems. Knowledge Based systems as Expert systems, Decision Support Systems (DSS) or Detections Systems (DS); Knowledge Based Systems vs Expert Systems, Advantage and disadvantage of Knowledge Based Systems vs Expert Systems. Practical case studies of expert systems, DSS and DS. (12)
Textbooks/Reference books	**Text Books:** 1. Artificial Intelligence and Knowledge Engineering, Winston, PHI publication , 2004. 2. Conceptual Information Processing, R.C Schank, Amsterdum North Holland, 2003. 3. Introduction to Expert Systems, Peter Jackson, Addison Wesley, 3rd. edition. 4. *Artificial Intelligence: A Modern Approach*, Russell, Stuart, and Peter Norvig. 4th. ed. Pearson, 2020. **Reference Books:** 1. The basic concepts of knowledge engineering by Shank and J.G. Carbonell, PHI publication, 2003. 2. Principles of Artificial intelligence, Nillson, N.J., Morgan Kaufmann publication, 2004. 3. Knowledge Management, by Shelda Debowski, John Wiley & Sons publication,. 4. Machine Learning and Data mining: Methods and Applications, Michalski, Bratko, Kubat, Wiley.

Department of Computer Engineering				
Course Code	Title of the course		Total Number of contact hours	Credit

		Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90XX	Natural Language Processing	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))
Basics of probability and statistics Fundamentals of calculus and linear algebra Programming skills in Python	CE+EA
Course Outcomes	• CO1: Knowing the fundamental concepts underlying natural language processing (NLP) and its applications • CO2: Understanding morphology, tokenization and stemming, language modeling, POS Tagging • CO3: Understand approaches to syntax and semantics in NLP. • CO2: understand morphology, context free and context-sensitive grammar, parsing issues. • CO4: Understand approaches to discourse, generation, dialogue and summarization within NLP. • CO5: Understand ambiguity resolution • CO6: Understand ML application in NLG. • CO7: Understanding some NLP applications
Topics Covered	Introduction to NLP and Basic Text Processing (3) Spelling Correction, Morphology using FST (3) Language Modelling, smoothing for language modelling (3) POS tagging , Models for Sequential tagging – MaxEnt, CRF (4) Syntax – Constituency Parsing, Dependency Parsing (5) Semantics – Lexical, WordNet and WordNet based Similarity measures, Distributional measures of Semantics , Lexical Semantics, Word Sense Disambiguation (7) Topic Models (3) Entity Linking, Information Extraction: Introduction to Named Entity Recognition and Relation Extraction (4) Text Summarization, Text Classification (3) Natural Language generation – using ML in NLG (3) Applications: Sentiment Analysis and Opinion Mining, Text Summarisation and classification, question answering, etc. (4)
Textbooks/Reference books	Jurafsky, David, and James H. Martin. Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition. Prentice-Hall, 2000. ISBN: 0130950696. Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008 Manning, Christopher D., and Hinrich Schütze. Foundations of Statistical Natural Language Processing. Cambridge, MA: MIT Press, 1999. ISBN: 0262133601.

	Machine Learning and Data mining: Methods and Applications, Michalski, Bratko, Kubat, Wiley.

<table>
<tr><td colspan="9">Department of Computer Science and Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CSE 90**</td><td>Deep Learning</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="2">Linear algebra, Calculus, Probability and statistics, Machine Learning</td><td colspan="6">CE+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the mathematical, statistical and computational challenges of building stable representations for high-dimensional data, such as images, text and data.
CO2: To obtain a concept of deep learning and its advantages.
CO3: To understand deep network models, optimization for training of deep models.
CO4: To achieve the knowledge on some popular deep learning models.
CO5: To explore the research domain of deep learning.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Machine Learning Basics: Extracting meaning from data, expert system, learning algorithms, overfitting and underfitting, regularization, hyperparameters and validation sets, estimator, bias and variance, ML estimation, Bayesian statistics, supervised learning, unsupervised learning, Stochastic Gradient Descent, building a machine learning algorithm, challenges motivating Deep Learning. (8)
Fundamentals of feedforward networks:
Single-layer and multilayer feedforward networks, Neural Network Graphs, activation functions, deep feedforward networks, hidden units, Learning XOR, gradient-based learning, Back-propagation algorithm and other differentiation algorithms. (4)
Regularization for deep learning
Parameter Norm Penalties, Norm Penalties as Constrained Optimization, Regularization and Under-Constrained Problems, Dataset Augmentation, Early Stopping, Sparse Representations, Dropout. (5)
Optimization for Training Deep Models:
How Learning Differs from Pure Optimization, Challenges in Neural Network Optimization, Basic Algorithms, Parameter Initialization Strategies, Algorithms with Adaptive Learning Rates, Approximate Second-Order Methods, Batch Normalization. (5)
Convolutional Networks:
The Convolution Operation, Pooling, Variants of the Basic Convolution Function, Structured Outputs, Structured outputs and datatypes. (4)
Sequence Modelling, Recurrent Neural Networks (RNN):
Unfolding Computational Graphs, RNNs, Bidirectional RNNs, LSTM. (5)
Autoencoders:
Undercomplete Autoencoders, Regularized Autoencoders, Stochastic Encoders and Decoders, Denoising Autoencoders, Contractive Autoencoders. (5)
Some Popular Deep networks and Applications: Generative Adversarial Networks, VGG net, ResNet, Inception Net. Applications of deep learning. (6)</td></tr>
</table>

Text Books, and/or reference material	Text Books: 17. I. Goodfellow, Y. Bengio, and A. Courville, Deep Learning, The MIT Press, 2017. 18. Charu C. Aggarwal, Neural Networks and Deep Learning, Springer, 2018. Reference Books: 6. Deep Learning, From Basics to Practice, Vol 1 and Vol 2, A. Glassner, Published by The Imaginary Institute, Seattle, WA, 2018 7. F. Chollet, Deep Learning with Python, Manning Publications Co., 2018. 8. N. Buduma, Fundamentals of deep learning: Designing Next-Generation Machine Intelligence Algorithms, O'REILLY, 2017

Department of Biotechnology							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Deep Learning for Image Analysis	PEL	3	0	0	3	3
Basics of image processing, probability and statistics, linear algebra, Fourier transform, etc.		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• CO1: To develop the idea of using deep learning models for image preprocessing and image restoration problems. • CO2: To learn about the principles of deep learning models used for image classification and segmentation. • CO3: To understand the deep learning models for image representation. • CO4: To apply deep learning models to state-of-the-art image processing problems.
Topics Covered	1) Introduction to artificial neural network, deep learning for visual data, data-driven image classification, linear classification, activation functions, various cost functions, gradient-based optimization with backpropagation. [6] 2) Introduction to different deep learning models: Convolutional Neural Networks (CNNs), Long Short Term Memory Networks (LSTMs), Recurrent Neural Networks (RNNs), Generative Adversarial Networks (GANs), Deep Belief Networks (DBNs), Restricted Boltzmann Machines (RBMs), Autoencoders, Transfer Learning, Deep Neural Networks (DNN), R-CNN, etc. [12] 3) Introduction to image processing, image enhancement, image restoration, image classification and recognition, image segmentation and image representation. [8] 4) Applications of deep learning models in image enhancement, image restoration, image classification, image segmentation and image representation. [16]
Text Books, and/or reference material	Text Books: 1. Deep Learning By Ian Goodfellow, Yoshua Bengio and Aaron Courville, MIT Press 2. Deep Learning: Methods and Applications By Li Deng and Dong Yu, Nowpublishers 3. Neural Networks and Deep Learning By Michael Nielsen, Determination Press 4. Deep Learning with Python by Francois Chollet, Manning Publications 5. Digital Image Processing by Gonzalez and Woods, Prentice Hall 6. Fundamentals of Digital Image Processing by Anil. K. Jain, Prentice Hall.

Department of Computer Science and Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90**	Information Retrieval	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Linear algebra, Probability and statistics, Machine Learning		CE+EA					

Course Outcomes

- CO1: To understand the underlined problems related to Information Retrieval.
- CO2: To be familiar with various algorithms and systems
- CO3: Analyze the performance of information retrieval using advanced techniques such as classification, clustering, and filtering
- CO4: To understand the evaluation strategies

Topics Covered

Introduction to Information Retrieval:
Basic concept of information retrieval, Practical issues, The Retrieval process. (2)

Modelling:
A Taxonomy of Information Retrieval Models,
Classic Information Retrieval: Basic Concepts, Boolean Model, Vector Model, Probabilistic Model, Comparison of Classic Models.
Set Theoretic Models: Fuzzy Set Model, Extended Boolean Model.
Algebraic Models: Generalized Vector Space Model, Latent Semantic Indexing Model, Neural Network Model.
Probabilistic Models: Bayesian Networks, Inference Network Model, Belief Network Model.
Structured Text Retrieval Models: Model Based on Non-Overlapping List, Model Based on Proximal Nodes.
Models for Browsing: Flat Browsing, Structure Guided Browsing, the hypertext model. (12)

Retrieval Performance Evaluation:
Introduction, Recall and Precision, Alternative Measures, F-measure, kappa measure.
Reference Collections: TREC Collection, CACM and lSI Collections, Cystic Fibrosis Collection. (3)

Indexing and Index Compression:
Basic concept, Dictionary, Inverted Index, Forward Index, Partitioning, Caching, Dictionary compression, Posting file compressing. (5)

Text Classification and Filtering:
Introduction to text classification. Naive Bayes models. Spam filtering. Vector space classification using hyperplanes; centroids; k Nearest Neighbours. Support vector machine classifiers. Kernel functions. Boosting. (7)

Text Clustering:
Clustering versus classification. Partitioning methods. k-means clustering. Mixture of gaussians model. Hierarchical agglomerative clustering. Clustering terms using documents.

Advanced Topics: (4)
Multimedia Information Retrieval: Similarity Queries, Feature-based Indexing and Searching, Spatial Access Methods, Searching in Multidimensional Spaces.
Web Searching: Introduction, Challenges, Characterizing the Web, Indexing, Spidering/Crawling, Search Engines, Browsing, Metasearchers, Searching using Hyperlinks, XML retrieval, Semantic web. (9)

Text Books, and/or reference material

Text Books:

19. C. D. Manning, P. Raghavan and H. Schutze, Introduction to information retrieval, Cambridge, University Press, 2008.

	20. R. Baeza-Yates, B. Ribeiro-Neto, Modern information retrieval, ACM Press / Addison Wesley, 1999 **Reference Books**: 9. G. Kowalski , Information Retrieval Architecture and Algorithms, Springer, 2011. 10. S. Buttcher, Charles L. A. Clarke, Gordon V. Cormack, Information Retrieval Implementing and Evaluating Search Engines, The MIT Press, 2010.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 9062	Human Activity Recognition	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic Mathematics – Knowledge and ability to use calculus, probability, and statistics are essential.		CT+EA					
Course Outcomes	• CO1: The objectives of this course is to provide foundations needed for the design, implementation, and evaluation of human activity recognition systems. • CO2: Will have knowledge to design and implement multiclassifier human activity recognition systems. • CO3: Will have knowledge to design and develop human activity recognition systems at large scales.						
Topics Covered	• Overview: Introduction, activity set, attributes and sensors, obtrusiveness, data collection protocol, recognition performance, energy consumption, processing. [7] • Methods: Feature extraction, learning, evaluation methodologies, evaluation metrics. [6] • Design Challenges of Human Activity Recognition Systems [3] • Pattern Classification Techniques: Introduction, Bayesian decision theory, maximum likelihood and Bayesian parameter estimation, non-parametric techniques, linear discriminant functions, multilayer neural networks, nonmetric methods. [9] • State-of-the systems: Online systems, supervised offline systems, semi-supervised approaches. [8] • Incorporating physiological signals: Description, data collection, feature extraction, evaluation, and confusion matrix. [6] • Enabling real time systems: Existing systems, novel systems, evaluation. [5] • Multiple classifier systems: Types of systems, classifier level approaches, combination level approaches, probabilistic strategies, evaluation. [6] • Other methods: Motion templates, temporal methods, discriminative methods. [4]						

Text Books, and/or reference material	**Text Books:** 5) Miguel A. Labrador, Oscar D. Lara Yejas, Human Activity Recognition: Using Wearable Sensors and Smartphones, CRC Press, 2013. 6) Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition, Wiley, 2000. **Reference Books:** 7) Yun Fu, Human Activity Recognition and Prediction, Springer, 2015.

Department of Computer Science and Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE9071	Fundation of Cryptography	PEL	3	0	0	3	3
Pre-requisite		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	• CO1: Introduce to the basic mechanisms of Cryptography • CO2: Notion of computationally hard problems and their applications • CO3: Notion of information theoretic notation and its application • CO4: The attack and withstands
Topics Covered	**Introduction:** Security architecture for Open Systems Interconnection, Different Attack models, Adversarial Behavior. (3) Classical and modern cryptographic techniques, Pseudorandom function, Family of pseudorandom functions, One-way-trapdoor function, statistical properties of random sequences, Computationally bounded & unbounded settings. (3) **Basic Number Theory:** Properties of Prime number, Additive and multiplicative group, Quadratic residue, Primality test. (8) **Confidentiality: Symmetric Encryption:** - DES, AES, mode of different encryptions **Asymmetric Encryption:** - RSA, Rabin's, El Gamaletc, Attacks and Countermeasures (10) Pseudo-number generation, Stream cipher, LFSR (4) **Message Integrity:** Cryptographic hash function, Birthday Paradox, Application of hashing. Message Authenticity, MAC (4) **Digital signature:** Entity authentication, Nonrepudiation, RSA, ElGamal and DSA, Forgery. (4) **Protocol Design**: SSL, PGP, TSL etc. (3) **Advanced topics:** Shamir Secret Sharing, Deniability and Undeniable signature. (3)
Text Books, and/or reference material	Text Books: 1. Hand book of Applied Cryptography, CRC Press (free ebook) 2. Cryptography: Theory and Practice, Douglas Robert Stinson, Maura Paterson 3. Cryptography and Network Security Principles and Practices: William Stallings. 4. Introduction to Modern Cryptography: Jonathan Katz, Yehuda Lindell Reference Books: 1. A Course in Number Theory and Cryptography, N Koblitz 2. Public-Key Cryptography: Theory and Practice, Abhijit Das, C. E. VeniMadhavan

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CSE90xx</td><td>Cryptology and Cryptanalysis</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisite</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">CSE9071 –Cryptography
Or basic knowledge of cryptography</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Understanding the computational hardness and trap-door function.
• CO2: Understanding the notion of information theoretic security.
• CO3: Aware of different sub-exponential algorithms
• CO4: Understanding the side channel attack</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: The notion of public key encryption and private key encryption. Zero-knowledge protocols, Authentication protocols. (4)
Affine Transformation: Differential Cryptanalysis and linear cryptanalysis. Case study of DES attack. Model of AES. Meet-in-the-Middle attack, Distinguisher, Related-key attack. (8)
Factorization and Index Calculation: Different factorization and Index calculation methods. rho-methods, factor-base method, quadratic sieve method, number theory sieve method. quantum method. Lattice-based cryptanalysis (12)
Hash Table attack: Birthday attack, Collision attack, Rainbow table attack, (4)
Protocol Modeling: Modeling of cryptography protocols. Modeling tools: ProVerif, Avispa and SPIN. Notion of Universally Composibility (UC) model. (8)
Side Channel Attack: Different types of side channel attacks. Attack model, measuring and analyzing methods. Some case study: timing attack, AES S-box attack. Withstand of side channel attacks: Different techniques and measures. (8)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Attacks on Hash Functions and Application: Marc Stevens
2. Prime Numbers a Computational Perspective: Crandall, Richard, Pomerance, Carl
3. Algorithmic Cryptanalysis: Antoine Joux
Reference:
1. Automatic Cryptographic Protocol Verifier, User Manual and Tutorial: https://prosecco.gforge.inria.fr/personal/bblanche/proverif/
2. Avispa: http://www.avispa-project.org/</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CSE 90xx</td><td>Biometrics</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
</table>

Basic Mathematics – Knowledge and ability to use calculus, probability, and statistics are essential.		CT+EA
Course Outcomes	• CO1: The objectives of this course is to provide foundations needed for the design, implementation, and evaluation of large-scale biometric systems. • CO2: Will have enough details to design and implement multimodal biometric systems. • CO3: Will have necessary technical knowledge to implement identity management systems.	
Topics Covered	8) Biometrics Overview: Introduction, characteristics of biometric systems, biometric functionalities, biometrics system errors, design cycles of biometric systems, applications of biometric systems, security and privacy issues. [4] 9) Image Processing Techniques: What is image processing?, origin of image processing, fundamental steps in digital image processing, components of image processing system, image sensing and acquisition, image sampling and quantization, basic relationships between pixels. [3] 10) Filtering: Background, basic intensity transformation functions, histogram processing, fundamentals of spatial and frequency domain filtering, smoothing filters, sharpening filters, Discrete Fourier Transform, Fast Fourier Transform. [3] 11) Pattern Classification Techniques: Introduction, Regression techniques, PCA, LDA, SVM, Decision tree, Random forest, Bayesian classifier, etc. [6] 12) Deep Learning Models: Convolutional Neural Networks (CNNs), Long Short Term Memory Networks (LSTMs), Recurrent Neural Networks (RNNs), Generative Adversarial Networks (GANs), Deep Belief Networks (DBNs), Restricted Boltzmann Machines (RBMs), Autoencoders, Transfer Learning, Deep Neural Networks (DNN), R-CNN, etc. [10] 13) Fingerprint Recognition: Introduction, ridge pattern, fingerprint acquisition, feature extraction, matching, and fingerprint synthesis. [3] 14) Face Recognition: Introduction, image acquisition, face detection, feature extraction, matching and advanced topics. [4] 15) Iris Recognition: Introduction, iris recognition systems, image acquisition, iris segmentation, iris normalization, iris encoding and matching, iris quality and performance evaluation. [4] 16) Multi-modal Biometric Systems: Introduction, sources of multiple evidence, acquisition and processing architecture, fusion levels. [4] 17) Palmprint biometrics. [1]	
Text Books, and/or reference material	**Text Books:** 7. Anil K. Jain, Arun Ross, and Karthik Nandakumar, Introduction to Biometrics, Springer, 2011. 8. J. L. Wayman, Ail K. Jain, D. Maltoni, D. Maio, Biometric Systems: Technology, Design and Performance Evaluation, Springer, 2005. 9. R. M. Bolle, J. Connell, S. Pankanti, N. K. Ratha, A. W. Senior, Guide to Biometrics, Springer, 2004.	

	10. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition, Wiley, 2000. 11. R.C. Gonzalez and R. E. Woods, Digital Image Processing, Pearson, 2009. **Reference Books:** • D. R. Kisku, P. Gupta and M. Tistarelli, Multibiometrics Systems: Modern Perspectives to Identity Verification, LAMBERT Publishing, 2012. • D. R. Kisku, P. Gupta and J. K. Sing, Advances in Biometrics for Secure Human Authentication and Recognition, CRC Press, Taylor & Francis, 2013. • D. R. Kisku, P. Gupta and J. K. Sing, Design and Implementation of Healthcare Biometric Systems, IGI Global, 2019. • M. Dawson, D. R. Kisku, P. Gupta, J. K. Sing and W. Li, Developing Next-Generation Countermeasures for Homeland Security Threat Prevention, IGI Global, 2016.

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 9056	Information and System Security	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Operating Systems, Computer Networks and basics of Cryptography		CT+EA					
Course Outcomes	• CO1: Will provide foundations needed for the design and implementation of Secure Computing Systems. • CO2: Will have enough details to design and implement various Security Mechanisms. • CO3: Will have necessary technical knowledge to Inspect for Security Features of Computing systems						
Topics Covered	• Fundamental Aspects of Security – Security Goals, CIA, Information Assurance, Secure Computing System Design Approaches, Fundamental Challenges, Basic Vulnerabilities and Attacks [6] • Mathematical Models of Information Flow and Security Inferences, Computational Challenges of Inference Controls with case studies of Parallel Programs and Covert Channels. [6] • Security Mechanisms – Redundancy, Isolation and Indistinguishability with Practical Examples of all such. [10] • Security Controls – Permissive, Prohibitive, Proving Authenticity, Access Control Mechanisms with implementation examples of all such. [6] • Security Architecture Design at each level of Hardware and OS Kernel, Device Drivers, Network and Middleware, Programming Languages for establishing Integrity and Authenticity and Trust among instances of each such and their interactions. Examples of Security Certificates and Credentials and establishing Trust, Firewalls, IDS. [10] • Case Study: Security Analyses of The Linux Kernel for X86-64 Arch -- Memory and Address protection: x86/x86_64 architectures, Memory protection, Application						

	Security, File System Protection Mechanism, Web Application Security, User Authentication, Access Control [4]
Text Books, and/or reference material	**Text Books:** • Foundations of Information Security by Jason Andress • Elementary Information Security by Richard E Smith **Reference Books:** • Information Security Principles and Practice by Mark Stamp, Wiley • Understanding the Linux Kernel by Bovet Cessati

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90xx	Secure Multiparty Computation	PEL	3	0	0	3	3
Pre-requisite		Course Assessment methods (Continuous (CT) and end assessment (EA))					
CSE9071 –Cryptography Or basic knowledge of cryptography		CT+EA					

Course Outcomes	• CO1: Understanding secure computation in the distributed environment. • CO2: Analysis of semi-honest and malicious adversary in the distributed setting. • CO3: The fairness and correctness in presence of malicious parties. • CO4: Understanding the difference between computation on encrypted date and computation on shared secret.
Topics Covered	**Introduction**: Different notions of secure computation on distributed environment. Notion of privacy, anonymity and data-independent computation. Notion of semi-honest and malicious adversary, Notion of computationally bounded and computationally unbounded setting, Fairness, Correctness etc. (8) **Secret Sharing**: Additive Secret Sharing, Shamir's Secret Sharing, Fault tolerance secret sharing, Arithmetic on Shamir's secret, Verifiable Secret Sharing. Fault tolerance secret sharing (10) **Garble Circuit**, 2-party computation, Arithmetic Circuit, Arithmetic Black Box, (6) **Oblivious Transfer**: Single bit, multiple bits, OT Extension. (5) **Zero-Knowledge Proof**: Interactive and non-interactive, concurrent. (5) **Some applications:** Byzantine Agreement and its feasibility, Distributed Key Generation, Privacy preserving string matching, online voting and auction, and Bitcoin architecture. (8)
Text Books, and/or reference material	Text Books: 1. Secure Multiparty Computation: Ronald Cramer, Ivan Bjerre Damgård, Jesper Buus Nielsen 2. Efficient Secure Two-Party Protocols: Techniques and Constructions: Carmit Hazay, Yehuda Lindell 3. Concurrent Zero-Knowledge: With Additional Background by Oded Goldreic: Alon Rosen

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 9056	Digital Forensics	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Operating Systems, Computer Networks and basics of Cryptography	CT+EA

Course Outcomes	• CO1: Will provide detailed understanding of the Digital Forensic process • CO2: Will have enough details to indulge in experiments concerning examination of forensic readiness of systems • CO3: Will have necessary technical knowledge about different security attack scenarios
Topics Covered	**Cyber Security** Basics of Cyber Security, Technology and Forms of Cyber Crimes, Frauds Malware, Virus, Worm, Trojans, Cyberwar and Cyber defence, Cybercrime: Computer Fraud and Abuse Act. Security Strategies, Securing Critical Infrastructures **Digital Forensics** Introduction to Forensics Legal issues, context, and digital forensics. Overview of Digital investigation: The Need for Digital Forensics and Types of Digital Forensics: File System Forensics, Memory Forensics, Network Forensics, Cloud Forensics, Database and email forensics. Digital Evidences: Types and characteristics Challenges for Evidence Handling (Evidence collection, preservation, testimony) use of digital forensics tools. **Memory Forensics** History of Memory Forensics and Challenges, x86/x86_64 architectures Memory Acquisition, Live Collection in Linux with open-source tool LiME, Memory Analysis/examination using open-source tool Volatility Analysis Techniques: keyword searches, timelines, hidden data, application analysis, Command execution and User activity, Recovering and tracking user activity, Recovering attacker activity from memory, Evidence preservation and Report Generation **Network Forensics** Introduction to Network Forensics Introduction to Wireshark, understanding network Protocols with Wireshark, Packet Capture using Wireshark, tshark and tcpdump, Packet analysis. Artifact collection, Analysis/ examination of logs. **Cloud Forensics** Introduction to Cloud Forensics Challenges faced by Law enforcement and government agencies Cloud Storage Forensics: Evidence Source Identification and preservation in the cloud storage, Collection of Evidence from cloud storage services, Examination and analysis of collected data. Dropbox Analysis: Data remnants on user machines, Evidence source identification and collection, Examination and analysis of collected data

	Google Drive Analysis: Data remnants on cloud storages, Evidence source identification and collection, Examination and analysis of collected data Issues in cloud forensics
Text Books, and/or reference material	**Text Books:** Casey, Eoghan. Handbook of digital forensics and investigation, Academnic Press, 2009 **Reference Books:** • Sammons, John, and Michael Cross. The basics of cyber safety: computer and mobile device safety made easy. Elsevier, 2016. • Marjie T. Britz, Computer Forensics and Cyber Crime, Pearson, Third Edition. • Clint P Garrison, Digital Forensics for Network, Internet, and Cloud Computing A forensic evidence guide for moving targets and data. Syngress Publishing, Inc. 2010. • Bill Nelson, Amelia Phillips,Christopher Steuart, Guide to Computer Forensics and Investigations . Cengage Learning, 2014 • Incident Response & Computer Forensics by Kevin Mandia, Chris Prosise, Wiley. • Cory Altheide, Harlan Carvey, Digital Forensics with Open-Source Tools, Syngress imprint of Elsevier.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90XX	Cyber Security	PEL	3	0	0	3	3
Pre-requisites: NIL		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**					
Course Outcomes	At the completion of this course students will be able to: • CO1: Understand the cyber laws. • CO2: Familiarize various types of cyber-attacks and cyber-crimes. • CO3: Learn the defensive techniques against these attacks. • CO4: Understand different privacy issues.						
Topics Covered	**UNIT-I**: **I**ntroduction to Cyber Security: Basic Cyber Security Concepts, layers of security, Vulnerability, threat, Harmful acts, Internet Governance – Challenges and Constraints, Computer Criminals, CIA Triad, Assets and Threat, motive of attackers, active attacks, passive attacks, Software attacks, hardware attacks, Spectrum of attacks, Taxonomy of various attacks, IP spoofing, Methods of defence, Security Models, risk management, Cyber Threats-Cyber Warfare, Cyber Crime, Cyber terrorism, Cyber Espionage, etc., Comprehensive Cyber Security Policy. (7L) **UNIT-II**: **Cyberspace and the Law & Cyber Forensics:** Introduction, Cyber Security Regulations, Roles of Implementation, International Law. The INDIAN Cyberspace, National Cyber Security Policy, Historical background of Cyber forensics, Digital Forensics Science, The Need for Computer Forensics, Cyber Forensics and Digital evidence, Forensics Analysis of Email, Digital Forensics Lifecycle, Forensics Investigation, Challenges in Computer Forensics, Special Techniques for Forensics Auditing. (5L) **UNIT-III Cybercrime: Mobile and Wireless Devices:** Introduction, Proliferation of Mobile and Wireless Devices, Trends in Mobility, Credit card Frauds in Mobile and Wireless Computing Era, Security Challenges Posed by Mobile Devices, Registry Settings for Mobile Devices, Authentication service Security, Attacks on Mobile/Cell Phones, Mobile Devices: Security Implications for Organizations, Organizational Measures for Handling Mobile, Organizational Security Policies and Measures in Mobile Computing Era, Laptops..						

	(8L) **UNIT-IV**: **Cyber Security: Organizational Implications:** Introduction cost of cybercrimes and IPR issues, web threats for organizations, security and privacy implications, social media marketing: security risks and perils for organizations, social computing and the associated challenges for organizations. Cybercrime and Cyber terrorism: Introduction, intellectual property in the cyberspace, the ethical dimension of cybercrimes the psychology, mind set and skills of hackers and other cyber criminals. (12L) **UNIT-V**: **Privacy Issues:** Basic Data Privacy Concepts: Fundamental Concepts, Data Privacy Attacks, Data linking and profiling, privacy policies and their specifications, privacy policy languages, privacy in different domains- medical, financial, etc. (5L) **UNIT-VI**: **Cybercrime: Examples and Mini-Cases.** (5L)
Text Books, and/or reference material	**Text Books:** 1. Cyber Security Essentials, James Graham, Richard Howard and Ryan Otson, CRC press **2.** Introduction to Cyber Security, Chwan-Hwa(john) Wu,J. David Irwin, CRC Press T&F Group. **Reference Books:** 1. Nina Godbole and Sunit Belpure, Cyber Security Understanding Cyber Crimes, Computer Forensics and Legal Perspectives, Wiley 2. B. B. Gupta, D. P. Agrawal, Haoxiang Wang, Computer and Cyber Security: Principles, Algorithm, Applications, and Perspectives, CRC Press

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90XX	Hardware Security	PEL	3	0	0	3	3
Pre-requisites: Foundation on Cryptography		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**					

Course Outcomes	At the completion of this course students will be able to: ● CO1: Understand different security threats on modern hardware design. ● CO2: Learn the various Hardware Security Primitives. ● CO3: Design and analyses the Side-channel Attacks and its impact on hardware security. ● CO4: Analyze different modelling attack on hardware and its prevention techniques. ● CO5: Understand different state-of-the-art defense techniques.
Topics Covered	**UNIT-I**: **Preliminaries:** Algebra of Finite Fields, Basics of the Mathematical Theory of Public Key Cryptography, Basics of Digital Design on Field-programmable Gate Array (FPGA), Classification using Support Vector Machines (SVMs) (5L) **UNIT-II**: **Useful Hardware Security Primitives:** Cryptographic Hardware and their Implementation, Optimization of Cryptographic Hardware on FPGA, Physically Unclonable Functions (PUFs), PUF Implementations, PUF Quality Evaluation, Design Techniques to Increase PUF Response Quality (5L) **UNIT-III Side-channel Attacks on Cryptographic Hardware**: Basic Idea, Current-measurement based Side-channel Attacks (Case Study: Kocher's Attack on DES), Design Techniques to Prevent Side-channel Attacks, Improved Side-channel Attack Algorithms (Template Attack, etc.), Cache Attacks. (8L)

	UNIT-IV: **Testability and Verification of Cryptographic Hardware:** Fault-tolerance of Cryptographic Hardware, Fault Attacks, Verification of Finite-field Arithmetic Circuits (12L) **UNIT-V**: **Modern IC Design and Manufacturing Practices and Their Implications:** Hardware Intellectual Property (IP) Piracy and IC Piracy, Design Techniques to Prevent IP and IC Piracy, Using PUFs to prevent Hardware Piracy, Model Building Attacks on PUFs (Case Study: SVM Modelling of Arbiter PUFs, Genetic Programming based Modelling of Ring Oscillator PUF) (5L) **UNIT-VI**: **Hardware Trojans**: Hardware Trojan Nomenclature and Operating Modes, Countermeasures Such as Design and Manufacturing Techniques to Prevent/Detect Hardware Trojans, Logic Testing and Side-channel Analysis based Techniques for Trojan Detection, Techniques to Increase Testing Sensitivity Infrastructure Security: Impact of Hardware Security Compromise on Public Infrastructure, Defence Techniques (Case Study: Smart-Grid Security) (7L)
Text Books, and/or reference material	**Text Books:** 3. Debdeep Mukhopadhyay and Rajat Subhra Chakraborty, "Hardware Security: Design, Threats, and Safeguards", CRC Press 4. Mark Tehranipoor, Swarup Bhunia, Hardware Security: A Hands-on Learning Approach 5. Mohammad Tehranipoor • Cliff Wang, Introduction to Hardware Security and Trust **Reference Books:** 3. Ahmad-Reza Sadeghi and David Naccache (eds.): Towards Hardware-intrinsic Security: Theory and Practice, Springer. 4. Ted Huffmire et al: Handbook of FPGA Design Security, Springer. 5. Stefan Mangard, Elisabeth Oswald, Thomas Popp: Power analysis attacks - revealing the secrets of smart cards. Springer 2007. 6. Doug Stinson, Cryptography Theory and Practice, CRC Press.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90XX	Blockchain Technology and its Applications	PEL	3	0	0	3	3
Pre-requisite		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	• CO1: Understanding the basic blockchain technology. • CO2: Understanding the distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods. • CO3: Understanding the smart contract. • CO4: Understanding the limitations and reality.						
Topics Covered	**Introduction**: Concept of distributed ledger, Byzantine Generals problem, Consensus algorithms and their scalability problems, Introduction to Bitcoin based cryptocurrency, Block datastructure, Block chaining mechanism. (4) **Minting operation:** Concept of PoW, other model – Proof of Stack, Proof or Memory, Proof of Burn etc. Green computing vs Proof systems. (3) **Consensus Model**: Fault tolerance model. P2P network model, Byzantine fault tolerance model, Longest chain model. (2)						

	Cryptographic Tools: Hash function, Collision resistant hash function, Elliptic Curve Digital signature (ECDSA). Markle tree representation, zero-knowledge proof. (4) **Bitcoin & Cryptocurrency:** Bitcoin network, Challenges and solutions, SIGHASH, Bitcoin scripting language and their use. (6) **Blockchain 2.0:** Blockchain network, Ethereum and Smart Contracts, The Turing Completeness of Smart Contract Languages, Application of smartcontract, Bitcoin scripting vs. Ethereum Smart Contracts. (6) **Solidity:** Introduction to Solidity programming language, Security issues, Basic coding metric, ERC-20, ERC-721, ERC-777, ERC-1155, Design of distributed applications (DApps). (5) **Blockchain 3.0:** Plug-and-play platform, Permission less vs. permission oriented platform, Blockchain testnet and mainnet, Deployment of smartcontarct. (4) **Anonymity:** Pseudo anonymous, pseudonym, transaction analysis, Sybil attack, Issues related to inheritance, Defining of cryptoasser, Regulation and legal supports. (5) **Application:** Application in IoT, HealthCare, Equity and Financial asset, Some case studies. (4)
Text Books, and/or reference material	Text Books: 1. Mastering in Blockchain: Lorne Lantz, Daniel Cawrey 2. Mastering Ethereum: Building Smart Contracts and DApps: Andreas M. Antonopoulos, **Wood Gavin** 3. Mastering Bitcoin: Programming the Open Blockchain: Andreas M. Antonopoulos

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Business Process Management in Software Science	PEL	3	0	0	3	3
<u>Pre-Requisite</u>: Basic Knowledge of Unified Modelling Language		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	•CO1: Learn the shared language and notations that are used by Information Technology (IT) specialist to communicate with business stakeholders. •CO2: To obtain a comprehensive idea to Manage, analyse, design, improve and reengineer business processes in industry setting scenarios. •CO3: Understand the core concepts of business processes and their components and to apply process analysis concepts and techniques. •CO4: Understand how the business process model may interface with business process management software suites (BPMS), service-oriented architecture platforms and other modern IT infrastructure platform software
Topics Covered	**UNIT-I: Introduction to Business Process Management:** Ingredients of a Business Process, the business process Lifecycle; Process Identification – Key Processes, Designing a Process Architecture, Construct Case/Function Matrices, Simple Case studies. (2L) **UNIT-II: Process Modelling Foundation:** Business Process Modelling and Notations (BPMN) core concepts, Branching and Merging, Exclusive Decisions, Parallel Execution, Inclusive Decisions, Information Artefacts. (4L)

	UNIT-III: Advanced Process Modelling: Process Decomposition, Process Reuse, Process Rework and Repetition; Handling Events, Handling Exceptions, Processes and Business Rules, Process Choreographies and orchestration. (4L) **UNIT-IV: Process Discovery:** The Setting of Process Discovery, Discovery Methods - Evidence-Based Discovery, Interview-Based Discovery, Workshop-Based Discovery, Strengths and Limitations; Process Modelling Method - Identify the Process Boundaries, Activities, Events, Resources Control Flow and Additional Elements, Process Model Quality Assurance (6L) **UNIT-V: Process Analysis:** Qualitative analysis **-** Value-Added Analysis, Root Cause Analysis Cause–Effect Diagram, Why–Why Diagram, Quantitative Analysis **-** Performance Measures, Flow Analysis, Calculating Cycle Time, Queueing Theory, Process simulation. (6L) **UNIT-VI: Process Based analysis:** Introduction to Analytical Hierarchy Process and Analytical Network Process. (4L) **UNIT-VII: Process Redesign:** The Essence of Process Redesign, Heuristic Process Redesign, Business Process Operation Heuristics, Business Process Behaviour Heuristics, Organization Heuristics, Information Heuristics, Deriving business Process from a Product Data Model (6L) **UNIT-VIII: Process-Aware Information Systems:** Types of Process-Aware Information Systems; Domain-Specific Process-Aware Information Systems; Business Process Management Systems - Advantages of Introducing a BPMS, Workload Reduction, Flexible System Integration, Execution Transparency, Rule Enforcement; Process Implementation with Executable Models - Identify the Automation Boundaries, Review Manual Tasks, Complete the Process Model, Granularity Level, Task Decomposition and sub-process creation, Task Aggregation; Execution Properties - Variables, Messages, Signals, Errors, and Their Data Types, Data Mappings, Service Tasks - Send and Receive Tasks, Message and Signal Events, Script Tasks, User Tasks, Sequence Flow Expressions, Implementing Rules (10L)
Text Books, and/or reference material	Text Books: 1. Fundamentals of Business Process Management, Authors: Marlon Dumas Marcello La Rosa, Jan Mendling, Hajo A Reijers, Springer Heidelberg New York, ISBN 978-3-642-33142-8 2. BUSINESS PROCESS MODEL AND NOTATION SPECIFICATION VERSION 2.0 [https://www.omg.org/spec/BPMN/2.0/About-BPMN/] 3. Business Process Management For Dummies®, 4th IBM Limited Edition Published by John Wiley & Sons, Inc..

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Ontology Engineering	PEL	3	0	0	3	3
Pre-requisites:		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET [CA: 15%, MT: 25%, ET: 60%]					
Course Objective	At the completion of this course students will be able to:						

	CO1: Introduce students to a variety of informal methods and logic-based formalisms to analyse and capture the semantics of knowledge. CO2: Equip students with the basic toolset to develop ontologies using a range formalisms and choosing a formalism suitable for the scope and application of the ontology. CO3: Enable students to evaluate their own ontologies and ontologies from the literature.
Topics Covered	UNIT-I: Introduction: philosophical foundations, examples of ontologies, concepts, classes, relations, and properties, Ontologies as conceptual models: ER & UML diagrams; Foundational categories & relations (6L) UNIT-II: Informal Ontologies: Lexicons - associating form with meaning (example: Wordnet), Taxonomies (example: Snowmed CT), Taxonomies of relations (example: physical containment relations); Good ontology design - Ontology design methodology, analysing ontologies, Ontology evaluation. (4L) UNIT-III: Ontology Engineering: Constructing Ontology, Ontology Development Tools, Ontology Methods, Ontology Sharing and Merging, Ontology Libraries and Ontology Mapping, Logic, Rule and Inference Engines, abstraction levels of Ontology – Upper, Middle and Detailed (8L) UNIT-IV: Lightweight ontologies for the Semantic Web: Syntax vs. Semantics, Syntactic foundations: XML and URIs, Resource Description Framework (RDF) and RDF Schema, Linked Data. (8L) UNIT-V: First-order logic ontologies - Syntax and semantics of first-order logic, Structures, interpretations, models; Reasoning with first-order logic ontologies– CNF, skolemization, unification, Resolution-based theorem proving– Theorem proving with ontologies, SAT-based model finding - Common Logic syntax.(8L) UNIT-VI: The Web Ontology Language (OWL2) - OWL2 syntax and semantics, Description Logics – OWL2 syntax, Reasoning with OWL2, Expressiveness and tractability trade off; Advanced aspects of logic-based ontologies - Reference, domain, and application ontologies, Ontology patterns, Modules and relationships between ontologies, Ontology Verification and Definability. (8L)
Text Books, and/or reference material	Text Books: 1. Maria Keet, An Introduction to Ontology Engineering, College Publication. Allemang, D., & Hendler, J. Semantic Web for the Working Ontologist, Second Edition: 2. Effective Modeling in RDFS and OWL. Morgan Kaufmann Publishers. 3. Tom Heath and Christian Bizer (2011). Linked Data: Evolving the Web into a Global Data Space (1st edition). 4. Synthesis Lectures on the Semantic Web: Theory and Technology, Morgan & Claypool. Franz Baader, Diego Calvanese, Deborah L. McGuinness, Daniele Nardi, and Peter F. Patel-Schneider, editors. 5. The Description Logic Handbook: Theory, Implementation and Applications, Second Edition. Cambridge University Press. 6. Web Ontology Language (OWL), https://www.w3.org/OWL/

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90XX	Software Testing	PCR	3	0	0	3	3

Pre-requisites: Those who opted Advanced S/W Engg in pool-1 is not eligible		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))
		CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**
Course Outcomes	At the completion of this course students will be able to: ● CO1: Understand the evolution of software testing techniques, their goals and learn the various models of software testing. ● CO2: Generate test cases for software systems using black box and white box testing techniques. ● CO3: Carry out regression testing of software systems. ● CO4: Test conventional, object-oriented and web based software. ● CO5: Understand debugging software and types of debuggers.	
Topics Covered	**UNIT-I**: Introduction to software testing, Basic concepts, Verification and Validation, Black box testing: Boundary value testing, Equivalence class testing, State Table Based Testing, Decision Table Based Testing, Cause-Effect Graph based Testing, Positive and Negative Testing, Orthogonal Array Testing. [10L] **UNIT-II**: White box testing: statement coverage, Branch coverage, condition coverage, MC/DC, path coverage, McCabe's cyclomatic complexity, Data flow based testing, Mutation testing. [10L] **UNIT-III:** Static testing, Integration testing, System testing, Interaction testing, Performance testing, Regression testing, Error seeding, Debugging. [10L] **UNIT-IV**: Object-oriented software testing: issues in object-oriented testing, Fault based testing, test cases and class hierarchy, Scenario based Test design, Class testing: Random testing for object-oriented classes, Partition testing at the class level Inter class test case design: multiple class testing, tests derived from behavioural models, Testing web based systems, Test Adequacy Measurement and Enhancement: Control and Data flow Testing tools. [12L]	
Text Books, and/or reference material	**Text Books:** 1. C. J. Paul, Software testing: A craftsmen's approach, CRC Press , 2013 2. I. Somerville – "Software Engineering", Addison-Wesley **Reference Books:** 3. S. Desikan, R. Gopalswamy, Software Testing: Principles and Practices, Pearson , 2006 4. G. J. Myers, The art of software testing, Wiley Interscience New York , 2011	

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90XX	Software Project and Quality Management	PCR	3	0	0	3	3
Pre-requisites: Software Engineering		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**					
Course Outcomes	At the completion of this course students will be able to: ● CO1: Understand basic project attributes such as size, effort, cost etc.						

	• CO2: Learn the desirable responsibilities of a good project manager. • CO3: Measure length, volume, effort, time and cost of a project. • CO4: Schedule project activities using PERT and GANTT chart. • CO5: Handle various project risks and configuration management.
Topics Covered	**UNIT-I**: **Preliminaries:** Introduction to S/W project management, S/W project management competencies, responsibilities of a software project manager, Software process, S/W process models, project planning, organization of project team. (6L) **UNIT-II**: Estimation Techniques: S/W size estimation, estimation of effort & duration. COCOMO models, Putnam's work, Jensen's model, Halstead's software Science, CK Metrics. (10L) **UNIT-III:** Dependency & scheduling: PERT, CPM, Gantt Chart, staffing, Organizing a software engineering project. (8L) **UNIT-IV**: S/W configuration management, monitoring & controlling S/W projects, developing requirements, risk management, project tracking & control, communication & negotiating. (10L) **UNIT-V**: S/W quality, S/W quality engineering, defining quality requirements, quality standards, practices & conventions, ISO 9000, ISO 9001, S/W quality matrices, managerial and organization issues, defect prevention, reviews & audits, SEI capability maturity model, PSP, six sigma. (8L)
Text Books, and/or reference material	**Text Books:** 1. B. Hughes, M. Cotterell, Rajib Mall, Software Project Management, McGraw Hill , 2015 2. R. Walker, Software Project Management, Pearson , 2003 **Reference Books:** 7. R. H. Thayer, Software Engineering Project management, IEEE CS Press , 1988. 8. R. Pressman, Software Engineering: A Practitioner's approach, McGraw Hill , 2005.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Cloud Computing	PCR	3	0	0	3	3
Pre-requisites:		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET [CA: 15%, MT: 25%, ET: 60%]					

Course Objective	At the completion of this course students will be able to: CO1: The fundamental ideas behind Cloud Computing, the evolution of the paradigm, its applicability; benefits, as well as current and future challenges. CO2: The basic ideas and principles in data center design; cloud management techniques and cloud software deployment considerations. CO3: Understand the concept of virtualization and how this has enabled the development of Cloud Computing. CO4: Understand scaling, Storage model, Data processing service and cloud security.
Topics Covered	UNIT-I: Cloud Computing Overview: Origins of Cloud computing – Cloud components - Essential characteristics – On-demand self-service, Broad network access, Location independent resource pooling ,Rapid elasticity , Measured service, Comparing cloud providers with traditional IT service providers, Roots of cloud computing, Cloud Architectural

	influences – High-performance computing, Utility and Enterprise grid computing, Cloud scenarios – Benefits: scalability ,simplicity ,vendors ,security, Limitations – Sensitive information - Application development- security level of third party - security benefits, Regularity issues: Government policies. (8L) UNIT-II: Cloud Architecture- Layers and Models Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS), features of PaaS and benefits, Infrastructure as a Service (IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Cloud deployment model: Public clouds – Private clouds – Community clouds - Hybrid clouds - Advantages of Cloud computing. (8L) UNIT-III: Management of Cloud Services: Reliability, availability and security of services deployed from the cloud. Performance and scalability of services, tools and technologies used to manage cloud services deployment; Cloud Economics: Cloud Computing infrastructures available for implementing cloud based services. Economics of choosing a Cloud platform for an organization, based on application requirements, economic constraints and business needs. (10L) UNIT-IV: Defining the Clouds for Enterprise: Storage as a service, Database as a service, Process as a service, Information as a service, Integration as a service and Testing as a service. Scaling cloud infrastructure - Capacity Planning, Cloud Scale. Layered Data Processing Approach – Cloud, Fog and Edge. (6L) UNIT-V: Cloud Storage - Global storage management locations, scalability, operational efficiency. Global storage distribution; terabytes to petabytes and greater. Policy based information management; metadata attitudes; file systems or object storage. (4L) UNIT-VI: Cloud Security: Confidentiality, privacy, integrity, authentication, non-repudiation, availability, access control, defence in depth, least privilege, how these concepts apply in the cloud, what these concepts mean and their importance in PaaS, IaaS and SaaS. e.g. User authentication in the cloud; Cryptographic Systems- Symmetric cryptography, stream ciphers, block ciphers, modes of operation, public-key cryptography, hashing, digital signatures, public-key infrastructures, key management, X.509 certificates, OpenSSL. Multi-tenancy issues, Virtualized System Specific Issues. (6L)
Text Books, and/or reference material	Text Books: Cloud computing a practical approach - Anthony T.Velte , Toby J. Velte Robert Elsenpeter, TATA McGraw- Hill. Cloud Computing (Principles and Paradigms), Edited by Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90XX	Software Architecture	PEL	3	0	0	3	3
Pre-requisites:		Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))					
		CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**					
Course Outcomes	At the completion of this course students will be able to: CO1: Understand the fundamentals of software architecture. CO2: Study the various software Architectural Quality Attributes CO3: Learn the various software architecture design Patterns						

	CO4: Relate software architecture and software quality.
Topics Covered	**UNIT-I: Introduction:** Basic Concepts of Software Architecture, Terminologies - Architecture, Component, Connector, Configuration, Architectural Style, Architectural Pattern, Models, Processes, Stakeholders, etc.; Many-fold contexts of Architecture – Technical, Project Lifecycle, business cycle, architectural patterns, reference models - architectural structures, views, Style (6L) **UNIT-II**: **Architectural Quality Attributes:** Functionality and Architecture, Architecture and Quality Attributes, System Quality Attributes, Quality Attributes Scenario in Practice, Other System Quality Attributes. (4L) **UNIT-III: Architectural Tactics and Patterns:** Introduction, Design Patterns, Tactics, Patterns Catalogue – Module Pattern (Layered, Module Decomposition), Component and Connecter (Broker, Model-View-Controller, pipe-and-Filter, Client Server, Peer-to-Peer, Service Oriented Architecture, Publish-subscription, Shared Data), Allocation Pattern (Map-Reduce, Multi-Tier, Enterprise), Relationship of Tactics to Architectural Patterns. (6L) **UNIT-IV**: Applied Architectures and Styles: Distributed and Networked Architectures: REST and SOAP, **Architectural Modelling and Description:** Early Architecture Description Languages, Views and Viewpoints, Choosing the Views, Combining Views Domain and Style Specific ADLs, Extensible ADLs, Documenting Software architecture – Domain Specific Language Model, Model Driven Architecture and UML (8L) **UNIT-V**: **Designing and Documenting Architecture:** Design Strategy, The Attribute-Driven Design Method, The Steps of ADD; Documenting Software Architectures - Uses and Audiences for Architecture Documentation, Notations for Architecture Documentation, , Building the Documentation Package, Architecture Documentation and Quality Attributes. (6L) **UNIT-VI**: **Evaluation of Architecture**: Evaluation Factors, The Architecture Tradeoff Analysis Method (ATAM), Lightweight Architecture Evaluation, Architecture Conformance – By Construction, By analysis, by Static and Dynamic Aspects, by Functional and Non-Functional Aspects. (6L) **UNIT-VII**: **Implementation:** Concepts, The Mapping Problem, Architecture Implementation Frameworks, Evaluating Frameworks, Middleware, Component Models, and Application Frameworks, Building a New Framework, Concurrency, Generative Technologies, Ensuring Consistency; Existing Frameworks - Frameworks for the Pipe and Filter Architectural Style, Frameworks for the C2 Architectural Style, Framework Domain Specific Language; Implementation Case Study. (6L)
Text Books, and/or reference material	**Text Books:** 1. Len Bass, Paul Clements, & Rick Kazman. *Software Architecture in Practice (Thrid Edition)*. Addison-Wesley. 2. Richard N. Taylor, Nenad Medvidovic, & Eric M. Dashofy. *Software Architecture: Foundations, Theory, and Practice*. Wiley. 3. Frank Buschmann, Regine Meunier, Hans Rohnert, Peter Sommerlad, & Michael Stal. *Pattern-Oriented Software Architecture: A System of Patterns*. Wiley,

Department of Computer Science and Engineering				
	Title of the course		Total Number of contact hours	Credit

<table>
<tr><td>Course Code</td><td></td><td>Program Core (PCR) / Electives (PEL)</td><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td><td></td></tr>
<tr><td>CSE ****</td><td>Agent based System</td><td>PCR</td><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Basic Computer Logic, Algorithms, Distributed System</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: formulate definitions of the most important concepts and the methods for intelligent agents and multi-agent systems
• CO2: evaluate and use the most important concepts and the methods in the area for intelligent agents and multi-agent systems.
• CO3: To be able to describe the main principles of distributed AI and the use of techniques from AI in distributed environments.
• CO4: To classify different types of IA architectures and their 'components' (i.e., reactive, deliberative, social components), and the relations between these components.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">• Introduction and basic concepts for DAI (distributed artificial intelligence). (4)
• Coordination methods general models, joint coordination techniques, organizational structures, information exchange on the metalevel, multi-agent planning, explicit analysis and synchronisation. (10)
• Negotiation methods: principles, protocols, production sequencing as negotiations, conventions for automatic negotiations. (6)
• Interoperability: Methods for interoperation of software, speech acts, KQML, FIPA. (5)
• Multi-agent architectures: Low-level architectural support, DAI-testbeds, agent-oriented software development. (10)
• Agent theory: Fundamentals of modal logic, the BDI architecture. (5)
• Agent architectures: deliberative, reactive and hybrid architectures. (5)
• Mobile agents: requirements, implementation, safety for mobile agents, environments for mobile agents. Agent typology and technical questions. Applications. (6)
• Practical part of the course that contains exercises and a project that includes implementation of a multi-agent system. (5)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
3. "An Introduction to Multi Agent Systems Second Edition", Michael Wooldridge, John Wiley & Sons, 2009.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">4. "Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations", Y. Shoham and K. Leyton-Brown, Cambridge UP, 2008.
5. "Multi-Agent Systems", 2nd edition, G. Weiss, editor, The MIT Press, 2013.
6. Prof. Michael Rovatsos videos</td></tr>
</table>

<table>
<tr><td colspan="8">Department of Computer Science and Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CSE 90XX</td><td>Service Oriented Architecture</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
</table>

Pre-requisites:	Course Assessment methods (Continuous Assessment (CA), Mid-Term (MT), End Term (ET))
	CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**
Course Objective	At the completion of this course students will be able to: ● CO1: To understand the principles of service oriented architecture. ● CO2: To understand and describe the standards & technologies of services oriented system development. ● CO3: To analyse and select the appropriate framework components in the creation of web service solutions. ● CO4: To apply object-oriented programming principles to the creation of web service solutions.
Topics Covered	**UNIT-I**: **Introducing SOA:** Fundamental SOA-Common characteristics of contemporary SOA- Common misperceptions about SOA- Common tangible benefits of SOA- Common pitfalls of adopting SOA The Evolution of SOA:-An SOA timeline (from XML to Web services to SOA)- The continuing evolution of SOA (standards organizations and contributing vendors)- The roots of SOA (comparing SOA to past architectures) Web Services and Primitive SOA: The Web services framework- Services (as Web services)- Service descriptions (with WSDL)- Messaging (with SOAP), SOA Standards – OASIS Reference Model, S3, Enterprise Service Bus. (10L) **UNIT-II**: **SOA and Service-Orientation:** Principles of Service-Orientation-Service-orientation and the enterprise- Anatomy of a service-oriented architecture- Common principles of service-orientation How service-orientation principles inter-relate-Section-Service-orientation and object-orientation, Native Web service support for service-orientation principles. - Service Layers –Service orientation and contemporary SOA- Service layer abstraction-application service layer-Business service layer- Orchestration service layer-Agnostic services- Service layer configuration scenarios. (8L) **UNIT-III: Web Services and Contemporary SOA:** Message exchange patterns- Service activity-coordination-Atomic transactions- Business activities-Orchestration-Choreography; Web Services and Contemporary SOA(Issues) : Addressing- Reliable messaging- Correlation Policies- Metadata exchange- Security- Notification and eventing. (6L) **UNIT-IV**: **Building SOA (Planning and Analysis**): SOA Delivery Strategies- SOA delivery lifecycle phases- The top-down strategy- The bottom-up strategy- The agile strategy Service-Oriented Analysis (Introduction): Introduction to service-oriented analysis- Benefits of a business-centric SOA- Deriving business services. (6L) **UNIT-V**: **Service-Oriented Analysis:** Service modelling (a step-by-step process)- Service modelling guidelines- Classifying service model logic- Contrasting service modelling approaches (an example) (4L) **UNIT-VI**: **Service-Oriented Design**: Introduction to service-oriented design- WSDL-related XML Schema language basics- WSDL language basics- SOAP language basics- Service interface design tools Service-Oriented Design (SOA Composition Guidelines): Steps to composing SOA Considerations for choosing service layers and SOA standards, positioning of cores and SOA extensions Service-Oriented Design (Service Design): -Overview-Service design of business service, application service, 72asks centric service and guidelines Service-

	Oriented Design (Business Process Design): WS-BPEL language basics-WS-Coordination overview- Service-oriented business process design (a step-by-step process). (8L)
Text Books, and/or reference material	**Text Books:** 6. Thomas Erl ," Service-Oriented Architecture: Concepts, Technology & Design", Pearson Education Pte Ltd. 7. Thomas Erl,"SOA Principles Of Service Design"Pearson Exclusives 8. Tomas Erl and Grady Booch,"SOA Design Patterns"Printice Hall 2008

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 9042	**Game Theory and its Applications**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Algorithms, Data structures, Discrete Mathematics, and Probability.		CT+EA					
Course Outcomes	· CO1: Can have the efficiency to act in a strategic situation. · CO2: Can analyse the strategic interactions among agents. · CO3: Can understand the modern state of the art in Game Theory and its applications.						
Topics Covered	**Introduction**. (2) **Non-Cooperative Game Theory:** Introduction to Game Theory, Extensive Form Games, Strategic Form Games, Dominant Strategy Equilibrium, Pure Strategy Nash Equilibrium, Mixed Strategy Nash Equilibrium, Sperner's Lemma, Fixed Point Theorem and Existence of Nash Equilibrium, Computation of Nash Equilibrium, Complexity of Computing Nash Equilibrium, Matrix Games (Two Players Zero Sum Games), Bayesian Games, Subgame Perfect Equilibrium. (12) **Mechanism Design without Money:** One sided and two-sided matching with strict preferences, Voting theory, and Participatory democracy. (6) **Mechanism Design with Money:** Auction basics, sponsored search auctions, Revenue optimal auctions, VCG Mechanisms. (6) **Cooperative Game Theory**: Correlated Strategies and Correlated Equilibrium, Two Person Bargaining Problem, Coalitional Games, The Core, and The Shapley Value. (4) **Repeated Games and its Applications**. (4) **Applications: Incentive Study in -** P2P Networks, Crowdsourcing, Digital currency, Social networks, Reputation Systems. (10) **Some Special Topics -** Fair Division, Price of Anarchy, scoring rules, Hierarchy of equilibrium, Learning in Auction, Synergies between Machine Learning & Game Theory. (12)						

Text Books, and/or reference material	**Text Books:** 1. N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani. Algorithmic Game Theory. Cambridge University Press, New York, NY, USA, 2007, ISSN: 978-0521872829. 2. M. Maschler, E. Solan, and S. Zamir. Game Theory, Cambridge University Press; 1st Edition, ISSN: 978-1107005488, 2013. 3. Y. Narahari. Game Theory and Mechanism Design. World Scientific Publishing Company Pte. Limited, 2014, ISSN: 978-9814525046. 4. T. Roughgarden, Twenty Lectures on Algorithmic Game Theory, Cambridge University Press, 2016, ISSN: 978-1316624791. **Reference Book/Lecture Notes:** 1. T. Roughgarden, CS364A: Algorithmic Game Theory Course (Stanford University), 2013. 2. T. Roughgarden, CS269I: Incentives in Computer Science Course (Stanford University), 2016. 3. S. Barman and Y. Narahari, E1:254 Game Theory Course (IISc Bangalore), 2012.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 9067	**Randomized Algorithms**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Algorithms and Probability		CT+EA					
Course Outcomes	· CO1: To be able to model a problem using randomized algorithms, if it is necessary. · CO2: Comparing standard randomized algorithm with its non-randomized version through analysis. · CO3: Can learn tools and techniques for designing and analysing randomized algorithms.						

Topics Covered	**Introduction:** Overview and Motivational Examples. (2) **Tools:** · Indicator Random Variable, Linearity of expectation; Markov inequality; Chebyshev's inequality; Chernoff bound; Union bound with examples to Randomized algorithm design. (12) · Coupon Collection and Occupancy Problems. (4) · Conditional Expectation and Martingales. (4) · Balls, Bins and Random Graphs. (4) · Markov Chains and Random Walks. (4) · Probabilistic Method. (6) **Applications:** · Sorting; Selection; Data Structure; Graph Problems. (6) · Metric Embeddings. (3) · Online Algorithms. (4) · Algorithms for Massive Data Set include Similarity Search. (4) · Other Modern Applications. (3)
Text Books, and/or reference material	**Text Books:** 1. Rajeev Motwani and Prabhakar Raghavan, Randomized Algorithms, 2nd Edition, Cambridge University press, Cambridge, MA, 1995. 2. Thomas H. Cormen, Charles Leiserson, Ronald Rivest, and Clifford Stein. Introduction to Algorithms. 3rd ed. MIT Press, 2009. ISBN: 9780262033848. 3. M. Mitzenmacher and E. Upfal, Probability and Computing: Randomized Algorithms and Probabilistic Analysis, Cambridge University Press. 4. J. Kleinberg and E. Tardos, Algorithm Design,Pearson. **Reference Book/Lecture Notes:** 1. D. Karger, 6.856J/18.416J: Randomized Algorithm (MIT Course), Spring 2019. 2. Siddharth Barman and Arindam Khan, E0 234: Introduction to Randomized Algorithms (IISc.), Spring 2021 (Several links of other courses are provided). 3. A. Goel, CME 309/CS 365: Randomized Algorithm (Stanford Course), Winter 2012-13. 4. G. Valiant, CS265/CME309: Randomized Algorithms and Probabilistic Analysis (Stanford University Course), Fall 2018. 5. Dimitri P. Bertsekas and John N. Tsitsiklis, Introduction to Probability, 2nd Edition, Athena Scientific, July 2008. 6. T. Roughgarden, CS261: A Second Course in Algorithms (Stanford University), 2016 and Randomized Algorithms: COMS 4995 (2019)

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

CSE 90	Computational Geometry	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
A course on Design and analysis of algorithm	CT+EA
Course Outcomes	• CO1: To design 'new' geometric algorithms. • CO2: To map problems to computational geometric problems. • CO3: To solve a wide range of practical problems in a variety fields such as graphics, robotics, databases, sensor network • CO4: To read and understand algorithms published in journals.
Topics Covered	**Computational Geometry Introduction**: Historical perspectives, Geometric preliminaries, Convex Hull, Algorithms to find the Convex Hull of a point set in 2D plane: Graham's Scan Algorithm, Divide and Conquer algorithm, Output sensitive algorithm: Jarvis's March Algorithm, Lower bound analysis for Convex Hull Algorithm, Application Domains : Diameter of a point set [7] **Line Segment Intersection**: Line Segment Intersection, The Doubly-Connected Edge List, Computing the Overlay of Two Subdivisions, Boolean Operations [4] **Polygon Triangulation**: Guarding and Triangulations, Counting the number of triangulations in a convex polygon, Art Gallery Theorem, Monotone Polygon, Partitioning a Polygon into Monotone Pieces, Triangulating a Monotone Polygon, [5] **Orthogonal Range Searching**: 1-Dimensional Range Searching, Kd Trees, Range Trees, Higher-Dimensional Range Trees, Fractional Cascading. [5] **Point Location**: Point Location and Trapezoidal Maps, A Randomized Incremental Algorithm to compute a Trapezoidal Map and a Search structure, Kirkpatrick's planar point location problem [5] **Voronoi Diagram and Delaunay Triangulation:** Definition and Basic Properties of Voronoi Diagram, Computing the Voronoi Diagram: Fortune Sweep Algorithm, Divide and Conquer Algorithm. Closest pair Problems. Application of voronoi diagrams, Triangulations of Planar Point Sets, The Delaunay Triangulation, Computing the Delaunay Triangulation [8] **Arrangements and Duality:** Arrangement of lines, Zone theorem, Duality, Application of arrangements and duality, Ham Sandwich Cut [4] **Geometric Data Structure**: Interval Trees, Priority Search Trees, Segment Trees [4]
Text Books, and/or reference material	**Text Books:** 1. Mark de Berg, Marc van Kreveld, Mark Overmars, Otfried Cheong, **Computational Geometry: Algorithms and Applications**, Third Edition, Springer Verlag 2. Franco P. Preparata and Michael Ian Shamos, **Computational Geometry- An Introduction**, Springer Verlag 3. Joseph O' Rourke, **Computational Geometry in C**, Cambridge University Press **Reference Material:** 1. Lecture notes on Computational geometry by David Mount

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Computability Theory	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Formal Language and Automata Theory, Discrete Structures.	CT+EA

Course Outcomes	• CO1: The course would give sufficient insights in the evolution of **reasonable** and formal models of computation and overall development of the theory of Computability to define what is Computable. • CO2: The Course will enable students to perceive Computability Theory as a basis for Computational Complexity Theory and **efficient** computation. • CO3: The course will enable the students to infer **practical consequences** of the concepts and theorems at each stage and relate to applications of the theory in a natural way
Topics Covered	Review of: Basic Notations, Logic, Set Theory, Algebra (Structures, k-adic Representation, Partial and Total Functions), Formal Language Theory (Words and Languages). [2] Axioms, theories and Paradoxes-Models and Interpretations, Formal Axiomatic Systems, Formalization of Logic and Mathematics – Decidability, Completeness (Gödel's First Incompleteness Theorem), Consistency (Gödel's Second Incompleteness Theorem) and consequences. [4] Formal Models of Computation, Algorithms and Computability; General Recursive Functions, λ-Calculus, TMs, The Computability Thesis (Church Turing Thesis). [5] The Turing Machine – Basic Model, Generalized Models, Reduced Model, Equivalence between Models, The Universal Turing Machine -Coding and Enumeration, Evolution of the Modern Computer – The Generalized View (General Purpose Computers {GPC}), Formalization of Definition and Characterization for Design of Algorithms, Conceptualizing Operating Systems, Design of Random-Access Machines. [10] Semi-Decidable sets, Parametrization and Recursion Theorems (RT), Recursive Program Definition and Execution, Conceptualization of Function Calls in GPC. [2] Decidability, Semi-decidability and Undecidability in the Light of Turing Machine based Inferences, Computable and Incomputable Functions/Problems. [2] Computational Problems and Algorithm Design – The Decision, Search, Counting and Enumeration Problems. [2] Incomputable (Non-Computable) Problems – The Halting Problem, Properties of Turing Languages, The Post's Correspondence Problem, Program Termination, Correctness of Algorithms (and Programs), Word Problems, Existence of Zeros and Functions, Provability and Satisfiability of Formulas of the First order theory. [8] Proving Non-computability – Using Methods of Diagonalization and Reduction, Using the RT, Using Rice's Theorem. [2] Oracle TMs and Computation, Turing Reductions and Turing Degrees and Hierarchies of Unsolvability. [3] P, NP and Relative Computability. [2]
Text Books, and/or reference material	**Text Books:** Introduction to the Theory of Computation by Michael Sipser **Reference Books:** Handbook of Computability Theory by Edward Griffor Computability and Complexity Theory by Homer and Selman Computers and Intractability by Garey & Johnson

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

CSE 90	Approximation Algorithm	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
A course on Design and analysis of algorithm	CT+EA
Course Outcomes	• CO1: To become familiar with important algorithmic concepts and techniques needed to effectively deal with NP complete problems. • CO2: To design an approximation that is close to the optimal solution of the hard problems. • CO3: To determine whether a problem can be approximated or not. • CO4: To read and understand algorithms published in journals.
Topics Covered	**Introduction:** Lower bounding OPT; An approximation algorithm for vertex cover; Well-characterized problems and min-max relations; Traveling salesperson problem (TSP); Metric TSP - A simple factor 2 algorithm, Improving the factor to 3/2. Steiner tree problem and its 2-approximation algorithm. (6) **Greedy Approximation Algorithms:** The minimum multiway cut problem, SET cover problem, Hochbaum Mass shifting strategy for covering problem, Edge Disjoint Paths problem (8) **Rounding Data and Dynamic Programming:** Knapsack problem, An FPTAS for knapsack, Bin Packing, An asymptotic PTAS for Bin Packing, Euclidean TSP (8) **Local Search:** Max-Cut, Minimum Degree Spanning Tree (3) **Linear Programming:** Integer Linear Programming (ILP); Formulation of Vertex Cover, SET Cover and Max Flow using ILP; LP Rounding technique for producing approximation algorithms. (5) **Introduction to LP-Duality**: The LP-duality theorem, Min-max relations and LP-duality, The notion of integrality gap (3) **Randomized rounding of Linear Programs:** Maximum Satisfiability**,** SET cover (4) **Hardness of Approximation:** Reductions, gaps, and hardness factors, The PCP theorem, Hardness of MAX-3SAT, Hardness of MAX-3SAT with bounded occurrence of variables, Hardness of vertex cover and Steiner tree, Hardness of clique, Hardness of set cover -The two-prover one-round characterization of NP, The gadget, Reducing error probability by parallel repetition,The reduction (5)
Text Books, and/or reference material	**Text Books:** 1. David P. Williamson and David B. Shmoys, **The design of Approximation Algorithms**, Cambridge University Press 2. Vijay V. Vazirani, **Approximation Algorithms**, Springer Verlag

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	

<table>
<tr><td>CS 90</td><td>Computational Complexity Theory</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Basics of Algorithms and Probability</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">· CO1: To be able to understand the need for complexity analysis at a high level.
· CO2: To be able to analyze algorithmic problems under computational lens.
· CO3: Learning different hierarchies of complexity theory.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">● Basic Complexity classes
○ The computational models revisited (2)
○ NP and NP Completeness and its different hierarchies (2)
○ Time and space hierarchy theorems (2)
○ Space Complexity (2)
○ Polynomial hierarchy and alterations (3)
○ Circuit Complexity (3)
○ Randomized computations (3)
○ Interactive proofs (2)
○ Complexity of counting (2)
● Lower bounds for concrete computational models
○ Decision trees (2)
○ Communication complexity (3)
○ Circuit lower bounds (3)
● Advanced topics
○ Average case complexity and Levin's theorem (2)
○ Derandomization, Expanders, and Extractors (3)
○ Hardness amplification and error correcting codes (3)
○ PCP and hardness of approximation (3)
○ Logic in complexity theory (2)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Sanjeev Arora and Boaz Barak. Computational Complexity: A Modern Approach. Cambridge University Press.
2. Christos Papadimitriou. Computational Complexity. Pearson.
Reference Book/Lecture Notes:
1. Ryan O'Donnell, 15-855: Graduate Computational Complexity Theory (2017)
2. Van Melkebeek, CS 710 - Complexity Theory (2016).
3. Michael R. Garey and David S. Johnson. Computers and Intractability: A Guide to the Theory of NP-Completeness. W. H. Freeman</td></tr>
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<table>
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</table>

Course Code		Program Core (PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90	Computational Number Theory	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Fundamental of Cryptography	CT+EA

Course Outcomes	• CO1: Foundation of modern cryptography. • CO2: Learn Elliptic Curve cryptography • CO3: The paring concept • CO4: Skill development of cryptographic application development
Topics Covered	**Arithmetic of Finite Field**: Field and Field extension, Representation of Finite field, Polynomial – Basis representation, Properties of Finite Field – Multiplicative order, Normal form, Minimal polynomial, Alternative representation [6] **Arithmetic of Polynomial**: Polynomial over Finite Field, Polynomial arithmetic, Irreduciable polynomial, Testing irreducibility, Roots of a polynomial –Factoring, Polynomial over integer, rational and complex number, Discriminant, Hensel Lifting. [6] **Arithmetic of Elliptic Curve**: Elliptic curve over Finite field and Field extension, Elliptic curve arithmetic, Elliptic curve in characteristic 2 and 3, Affine and Projective plane, Rational function on curve, Endomorphism on Elliptic Curve, Divisor [8] **Pairing:** Weil Pairing, Miller's Algorithm, Tate Pairing, Distortion maps, Twists, Pairing Friendly Curve, Implementation algorithms , Elliptic curve point counting, Schoof's algorithm. [8] **Factorization Algorithms:** Quadratic Sieve method, Elliptic Curve Method, Number-Field Sieve method. [8] **Index Calculation Method:** Linear Sieve method, Residue-List Sieve method, Cubic Sieve method, Number-Field Sieve method. [4] **Pairing Based Cryptography:** Identity-Based encryption, Key Agreement based of pairing, Identity-based signature, Certificate less public key. [4]
Text Books, and/or reference material	**Text Books:** 1. Computational Number Theory: Abhijit Das, CRC Press. 2. Elliptic Curves: Number Theory and Cryptography, L. C. Washington, CRC press **3.** Guide to Elliptic Curve Cryptography: Darrel Hankerson, ,*Alfred J. MenezesScott Vanstone*, Springer

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<tr><td colspan="9">Department of Computer Science and Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>CS 90</td><td>Data Stream Algorithms</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Basics of Algorithms and Probability</td><td colspan="6">CT+EA</td></tr>
</table>

Course Outcomes	· CO1: To be able to understand the need for space-efficient algorithm design. · CO2: Designing faster algorithms for massive data sets. · CO3: Can analyze the algorithms for data streams..
Topics Covered	● Overview and motivational examples. (1) ● Finding frequent items deterministically. (2) ● Estimating the number of distinct elements. (2) ● A better estimate for distinct elements (2) ● Approximate counting (3) ● Finding frequent items via (linear) sketching (3) ● Estimating frequency moments. (2) ● The tug-of-War sketch. (2) ● Estimating norms using stable distribution (2) ● Sparse recovery (2) ● Weight based sampling (2) ● Finding the median (sublinear) (2) ● Geometric streams and coresets (3) ● Metric streams and clustering (3) ● Graph streams: basic algorithms (2) ● Finding maximum matching (2) ● Graph sketching (2) ● Counting triangles (2) ● Communication complexity and lower bounds (3)
Text Books, and/or reference material	**Text Books:** 1. Amit Chakraborti, Data stream algorithms (draft version). 2. S. Muthukrishnan, Data Streams: Algorithms and Applications, (Now publishers Inc) (This survey may supplement the book: https://www.cs.princeton.edu/courses/archive/spr04/cos598B/bib/Muthu-Survey.pdf) **Reference Book/Lecture Notes:** 1. Amit Chakraborti, CS 35/135: Data Stream Algorithms, Spring 2020 (Dartmouth) 2. T. Roughgarden, CS168: Modern Algorithmic Toolbox (with Greg Valiant) (Spring 2017)

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90	**Online Algorithms**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basics of Algorithms and		CT+EA					

Probability	
Course Outcomes	· CO1: To be able to understand the need for online algorithm design. · CO2: To be able to recognize a real life problem as an online algorithm design problem. · CO3: Can analyze the online algorithms..
Topics Covered	• Overview and motivational examples. (1) • Deterministic Online Algorithms. (2) • Randomized Online Algorithms. (2) • Some Classical Problems (list accessing, k-servers) (2) • Online Algorithms and Pricing (2) • Primal-Dual Method for Online Problems (3) • Online MaxSat and Submodular Maximization (2) • Advice Model. (2) • Dynamic Graph Algorithms (2) • Real Time Models (2) • Revocable Decisions, Parallel Threads, and Multiple Pass Online Models (2) • Alternatives to Competitive Analysis (2) • Stochastic Inputs (3) • Priority Model (3) • Online Learning (2) • Online Game Theory (2) • Online Advertising (2) • Finance (2) • Networking and Online Navigation (3)
Text Books, and/or reference material	**Text Books:** 1. Allan Borodin and Denis Pankratov, Online Algorithms (draft version, 2019). **Reference Book/Lecture Notes:** 1. Serge Plotkin, CS369 - Online Algorithms (2013) 2. T. Roughgarden, CS261: A Second Course in Algorithms (Stanford University), 2016.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90	**Algorithmic Mechanism Design**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					

Basics of Algorithms and Probability	CT+EA
Course Outcomes	· CO1: To be able to understand the need for Algorithmic Mechanism design (AMD). · CO2: To be able to recognize a real life problem as an AMD problem. · CO3: Learning tools to analyze AMD problems..
Topics Covered	● Overview and motivational examples. (1) ● Ascending Auctions. (1) ● Unit-Demand Valuations. (1) ● Crawford-Knoer Auction (2) ● Clinching Auction (1) ● Gross Substitutes (3) ● Submodular Valuations (2) ● MIR and MIDR Mechanisms. (2) ● Scaling Algorithms (1) ● Convex Rounding (2) ● Shrinking Auction (2) ● BIC Mechanisms (2) ● Black-Box Reductions (2) ● POA of Simple Auctions (2) ● Bayes-Nash POA (2) ● First-Price Auctions (2) ● Uniform-Price Auctions (2) ● Revenue Maximization (2) ● Border's Theorem (2) ● Optimal Mechanisms (2) ● Liquid Democracy and beyond (3) ● Other topics (3)
Text Books, and/or reference material	**Text Books:** 1. N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani. Algorithmic Game Theory. Cambridge University Press, New York, NY, USA, 2007, ISSN: 978-0521872829. 2. T. Roughgarden, Twenty Lectures on Algorithmic Game Theory, Cambridge University Press, 2016, ISSN: 978-1316624791. 3. J. D. Hartline, Mechanism Design and Approximation (online version). **Reference Book/Lecture Notes:** 1. T. Roughgarden, CS364B: Frontiers in Mechanism Design (Winter 2014, Stanford) 2. J. D. Hartline, CS 496: Mechanism Design (2018, 2016) 3. Ariel Procaccia, CS 238: Optimized Democracy (2021, Harvard University)

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Course	Title of the	Program	Total Number of contact hours	Cre

Code	course	Core (PCR) / Electives (PEL)					dit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CS 90	**Theory of Parallel Systems**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basics of Algorithms	CT+EA

Course Outcomes	CO1: To be able to understand the theoretical foundations of general-purpose parallel computing systems. CO2: To be able to recognize algorithmic underpinnings of parallel systems. CO3: Learning tools to analyze parallel systems. CO4: Learning to implement parallel programs.
Topics Covered	• Overview and motivational examples. (1) • Dynamic Multithreading. (3) • Cilk, Matrix Multiplication, and Sorting. (3) • Other implementation software for parallel programs. (1) • Understanding hardware, Serial Performance and Caching techniques (2) • Cache-Oblivious Algorithms (1) • Determinacy race in parallel programs and algorithms (2) • Upper and lower bounds for space requirement in parallel programs. (2) • Memory Contention: How to share memories to processors. (2) • Scheduling and its analysis (with Cilk) (3) • Memory Consistency (2) • Parallel storage allocation (2) • Competitive Snoopy Caching (2) • Snoopy Caching and Spin-Block Problem (2) • Hypercubic Networks (3) • Routing (2) • Permuting Data on Parallel Disks (3) • Sorting and Permuting (3) • Speculative parallelism (1) • Parallelism on Graphs with real life examples (2)
Text Books, and/or reference material	**Text Books:** 1. Thomas H. Cormen, Charles Leiserson, Ronald Rivest, and Clifford Stein. Introduction to Algorithms. MIT Press (2nd and 3rd Editions). **Reference Book/Lecture Notes:** 1. Bradley Kuszmaul, Charles Leiserson, et. al. SMA 5509:Theory of Parallel Systems (MIT). 2. C. Leiserson and J Shun, MIT 6.172: Performance Engineering of Software Systems, 2018.

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	Title of the course		Total Number of contact hours	Credit

<table>
<tr><td>Course Code</td><td></td><td>Program Core (PCR) / Electives (PEL)</td><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td><td></td></tr>
<tr><td>CSE90</td><td>Advanced Graph Theory</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">CSE90
(Advanced Graph Theory)</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• Understand the basic concept of graph and its properties and apply the basic properties of graph theory to prove different applications
• Discuss about chromatic characteristics, planar graph and solve various graph theory problems using planarity and coloring.
• Students can explore knowledge of graph theory to solve the technology driven and research oriented problems.
• Use a combination of theoretical knowledge and mathematical thinking to solve various computer science applications.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Fundamental concepts of graphs: Basic definitions, graphs and digraphs, properties, subgraphs, complementation; Incidence and adjacency matrices; Complete graphs, regular graphs; Petersen graph; Handshaking lemma; Bipartite graphs, Ramsey number, Isomorphism of graphs, Operation on graph. 6L
Connectivity: Vertex and edge connectivity, Cliques and independent sets; connected components, paths and cycles, cuts, blocks, k-connected graphs; Menger's theorem; diameter and shortest paths. 5L
Trees and forests: centers and centroids; spanning trees, Steiner trees; tree enumeration; Cayley’s theorem; Huffman coding, Prüfer codes. 6L
Graph traversal: Eulerian and Hamiltonian graphs; Dirac’s theorem; Fleury’s algorithm for finding Eulerian paths or cycles; Traveling Salesman problem. 3L
Directed graphs: Tournaments, directed paths and cycles, Eulerian digraphs, connectivity and strongly connected digraphs; directed acyclic graphs (DAG), topological sorting. 2L
Planarity: Plane and planar graphs, maximal planar graphs, Non-planarity of K5 and K3,3 ; Kuratowski’s theorem; planar dual; Euler’s formula. Planar embedding of trees and graphs; genus, thickness, and crossing number; 5L
Matching, Covering, Independent set: Maximum matching, perfect matching; Matching in bipartite graphs - Konig's theorem, Hall's marriage theorem; Matching in general graphs - Tutte's theorem; weighted matching; Latin square; Minimum covering; Maximum independent set 6L
Factor and Coloring: Factor of complete graph, Types - 1-factor, 2-factor ; Vertex and edge coloring, clique number and chromatic number; vertex coloring - Brooks'; theorem, Edge coloring - Vizing's theorem; Chromatic partitioning, Chromatic polynomial, Five color theorem for planar graphs; Four-color theorem for planar graphs; line graphs. 5L
Network flows: Flows and matching; max-flow min-cut theorem. 2L
Some graphs: Perfect graphs, Random graphs. 2L</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Douglas B. West. Introduction to Graph Theory. Pearson Education, Second Edition, 2000
2. R. Deistel. Graph Theory. Springer- Verlag NewYork 1997.
3. J. A. Bondy and U.S.R. Murty: Graph Theory, Springer, 2008.

Reference Books:
1. N. Deo. Graph Theory; With Applications to Engineering and Computer Science. PHI, 1974
2. S. Pirzada. An Introduction to Graph Theory. Orient Blackswan, 2014</td></tr>
</table>

	3. R. J. Wilson and J.J. Watkins. Graphs: An Introductory Approach. John Wiley and Sons Inc.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90	CAD for VLSI	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Digital Electronics, Computer Organisation, Algorithm Design..	CT + EA

Course Outcomes	• CO1: To visit the various stages of the VLSI design cycle and appreciate the role of automation therein. • CO2 : To appreciate how High Level Synthesis converts an HDL code into an architecture level design. • CO3 : To discuss the algorithmic approach to physical design. • CO4 : To emphasize the importance to testability measures in the design.
Topics Covered	VLSI Design cycle. Design styles. System packaging styles. Fabrication of VLSI devices. Design rules-overview. (5) HLS : Scheduling in High Level Synthesis. ASAP and ALAP schedules. Time constrained and Resource constrained scheduling. (5) HLS : Allocation and Binding. Datapath Architectures and Allocation tasks. (5) Partitioning. Clustering techniques. Group Migration algorithms. (3) Floorplanning. Constraint based Floorplanning. Rectangular Dualization. Hierarchical Tree based methods. Simulated Evolution approaches. Timing Driven floorplanning. (5) Placement. Simulation based placement algorithms. Partitioning based placement algorithms. Cluster Growth. (4) Global Routing. Maze Routing algorithms. Line probe algorithms. Shortest Path based algorithms. Steiner's Tree based algorithms. (4) Detailed Routing. Channel Routing Algorithms. Switchbox Routing. Over-the-cell routing. Clock and Power Routing. (4) Design for testability. Fault testing. Ad-hoc and structured DFT techniques. (7)
Text Books, and/or reference material	**Text Books** 1. Algorithms for VLSI Physical Design Automation. N.A.Sherwani. Kluwer Academic Publishers. 2. High-Level Synthesis : Introduction to Chip and System Design. Gajski et. al. . Kluwer Academic Publishers. 3. Digital Systems Testing and Testable Design. Abramovici et.al. Jaico Publications **Reference Books** 4. VLSI Physical Design Automation. Sadiq M. Sait and Habib Youssef. Kluwer Academic Publishers. 5. Algorithms for VLSI Design Automation. Sabih H. Gerez. Wiley India. 6. Essentials of Electronic Testing for Digital, Memory and Mixed Signal VLSI Circuits. Bushnell and Agrawal. Kluwer Academic Publishers.

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90	Cyber Physical Systems	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Computer Organisation, Computer Networks, Embedded Systems, Formal Languages and Automata.		CT + EA					

Course Outcomes

- CO1: Understand the core principles behind CPS
- CO2: Identify safety specifications and critical properties
- CO3: Understand abstraction in system designs
- CO4: Express pre- and post-conditions and invariants for CPS model.

Topics Covered

Unit 1 :What are Cyber-Physical Systems? [2 hours]
Cyber-Physical Systems (CPS) in the real world, Basic principles of design and validation of CPS, Industry 4.0, AutoSAR, IIOT implications, Building Automation, Medical CPS

Unit 2 : CPS - Platform components [8 hours]
CPS HW platforms - Processors, Sensors, Actuators (2 hrs)
CPS Network - WirelessHart, CAN, Automotive Ethernet (4 hrs)
Scheduling Real Time CPS tasks (2 hrs)

Unit 3 : Principles of Dynmical Systems [4 hours]
Dynamical Systems and Stability, Controller Design Techniques, Performance under Packet drop and Noise

Unit 4 : CPS implementation issues [10 hours]
From features to automotive software components, Mapping software components to ECUs CPS Performance Analysis - effect of scheduling, bus latency, sense and actuation faults on control performance, network congestion, Building real-time networks for CPS

Unit 5 : Intelligent CPS [12 hours]
Safe Reinforcement Learning, Robot motion control, Autonomous Vehicle Control Gaussian Process Learning, Smart Grid Demand Response, Building Automation

Unit 6: Secure Deployment of CPS [12 hours]
Secure Task mapping and Partitioning, State estimation for attack detection Automotive Case study : Vehicle ABS hacking, Power Distribution Case study :

	Attacks on SmartGrids
Text Books, and/or reference material	**Text Books** 7. Rajeev Alur, *Principles of Cyber-Physical Systems*, MIT Press, 2015. 8. E. A. Lee and S. A. Seshia, "Introduction to Embedded Systems: A Cyber-Physical Systems Approach", 2011. 9. T. D. Lewis "Network Science: Theory and Applications", Wiley, 2009. 10. P. Tabuada, "Verification and control of hybrid systems: a symbolic approach", Springer-Verlag 2009. 11. C. Cassandras, S. Lafortune, "Introduction to Discrete Event Systems", Springer 2007. 12. Constance Heitmeyer and Dino Mandrioli, "Formal methods for real-time computing", Wiley publisher, 1996

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSC - 2003	Advanced Computer Architecture	PCR	3	1	0	4	4
Pre-requisites		Digital Logic design Computer Organization Computer Architecture					
Course Outcomes	• CO1: To know about the classes of computers, and new trends and developments in computer architecture • CO2: To acquire knowledge about the various architectural concepts that may be applied to optimize and enhance the classical Von Neumann architecture into high performance computing systems. • CO3: To learn the basic design procedure for different levels of parallelism. • CO4: To learn the design issues relating to the architectural options. • CO5: To know the challenges faced in the implementation of these high performance system.						
Topics Covered	**UNIT 1: OVERVIEW OF VON NEUMANN ARCHITECTURE -** Instruction set architecture; Arithmetic and Logic Unit, Control Unit, Memory and I/O devices and their interfacing to the CPU, Measuring and reporting performance; CISC and RISC processors, Organization and function of components needed for a simple processor design, Outline of the principles of instruction set design and demonstration with the use of ARMv8-A Instruction Set Architecture. **[10]** **UNIT 2: PIPELINING -** Pipelining fundamentals, Linear and Nonlinear Pipeline Processors, Arithmetic and instruction pipelining, Pipeline hazards, Case study of Arm10 processor pipeline, Techniques for overcoming or reducing the effects of various hazards, Superscalar and super pipelined and VLIW architectures. **[10]** **UNIT 3: INSTRUCTION LEVEL PARALLELISM (ILP) -** Concepts and challenges; Techniques for increasing ILP - Basic Compiler Techniques for exposing ILP; Reducing Branch costs with prediction; Overcoming Data hazards with Dynamic scheduling; Hardware-based speculation, Advanced Techniques for						

	instruction delivery and Speculation, Case study of ILP concepts in the Cortex-A75, Cortex-A77, and Cortex-A55 processors. **[10]** UNIT 4: MULTIPROCESSORS ARCHITECTURES - Taxonomy of parallel architectures, Centralized shared-memory architecture: Synchronization, Memory consistency, Distributed shared-memory architecture, Interconnection networks, Topology, Different interconnection Networks, Routing Mechanism. **[10]** **UNIT 5: MEMORY HIERARCHY DESIGN** - Memory hierarchy, Cache Memory, Cache performance; Basic and Advanced optimizations of Cache performance, Cache coherence, Cache coherence protocols – Snoop based and Directory based protocols, Case study with Cortex-A9 processor. **[6]** **UNIT 6: MULTICORE ARCHITECTURE** - Multicore processors, Communication aspects, cache-coherence protocols and memory consistency, Case study with Cortex-A55. **[4]** **UNIT 7: SPECIALIZED PROCESSOR ARCHITECTURES** - Data flow computers, Systolic architectures, Vector processors, Graphics Processing Units (GPUs), Some cases studies e.g. ARM NEON, Scalable Vector Extension (SVE), Mali GPU G76, and Mali G77. **[4]** **UNIT 8: SYSTEM ON CHIP –** Application of various computer architecture concepts in modern day SoCs. [**2**]
Text Books, and/or reference material	**Text Books:** **1.** Computer Architecture, A Quantitative Approach – John L. Hennessey and David A. Patterson; 4th edition, Morgan Kaufmann. **2.** Advanced Computer Architecture Parallelism, Scalability, Programability – Kai Hwang; Tata Mc- Graw Hill. **Reference Books:** **1**. Computer architecture and parallel processing – Kai Hwang and Fayé Alayé Briggs; McGraw-Hill. **2**. Parallel Computer Architecture, A Hardware / Software Approach – David E. Culler, Jaswinder Pal Singh, Anoop Gupta; Morgan Kaufman. **3.** John Paul Shen and Mikko H. Lipasti, Modern Processor Design: Fundamentals of Superscalar Processors, Tata McGraw-Hill. **4.** M. J. Flynn, Computer Architecture: Pipelined and Parallel Processor Design, Narosa Publishing House. 5. Digital Design and Computer Architecture Arm Edition by Sarah L. Harris & David Money Harris **6**.ARM System-on-Chip Architecture by Steve B. Furber **7.**Computer Organization and Design, The Hardware/Software Interface Arm Edition by David A. Patterson and John L. Hennesy **8**. NPTEL/MOOC Course materials

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE90	Testing and Verification of VLSI Circuits	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Digital Electronics, Computer Organisation		CT+EA					
Course Outcomes	• CO1: To explain and exemplify basic and advanced concepts of Testing and Verification of Digital Circuits. • CO2: To understand fault modeling and test generation • CO3 : To fully appreciate the need for testability measures in the design stage of circuits. • CO4: To understand the use of formal models for verification of the circuit specs.						
Topics Covered	Introduction to VLSI testing and verification. Logic and Event Driven Simulation. Delay Models. (2) Fault Modeling. Single Stuck-at Fault model. Fault Collapsing. Fault Equivalence. Fault Domination. Checkpoint Theorem (5) Fault Simulation. Serial, Parallel, Deductive and Concurrent. (2) Test Generation. Boolean Difference Method. D-Algorithm. PODEM. FAN. (5) Testability Analysis (2) Design for Testability. Adhoc approaches. Scan based Design. Random Scan. Scan FF design. LSSD. Scan-Hold FF. (5) Built-in Self Test. Pseudo-Random Pattern Generation. LFSR. (5) PLA Testing. (3) Memory testing. (3) Formal verification. System Model. Temporal logics. Model Checking. BDD. Symbolic Model Checking. Bounded Model Checking. (10)						
Text Books, and/or reference material	Text Books 5. Essentials of Electronic Testing for Digital, Memory and Mixed Signal VLSI Circuits. Bushnell and Agrawal. Kluwer Academic Publishers. 6. Digital Systems Testing and Testable Design. Abramovici et.al. Jaico Publications. 7. Logic in Computer Science. Huth and Ryan. Cambridge University Press. Reference Books 3. Model Checking. Clarke et. al. MIT Press. 4. VLSI Test Principles and Architectures. LT Wang et.al. Morgan Kaufman.						

Department of Computer Science and Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
CSE 90XX	Embedded System Design	PCR	3	0	0	3	3
Pre-requisites:		Assessment					
Prerequisites: Computer Organization and Architecture		CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]**					
Course Outcomes	At the completion of this course students will be able to: • CO1: Understand the concept of embedded system and the architecture of such system. • CO2: Understand the role of controller, timer and interfaces for embedded system. • CO3: Design and analyzes the various scheduling algorithm and protocols for power						

	efficient embedded system. • CO4: Understand the concept of HW-SW partition and co-design principles. • CO5: Understand the modeling and specification of embedded system.
Topics Covered	**UNIT-I**: **Introduction to embedded system: -** Challenges in Embedded System Design, Processors: General Purpose and ASIPs Processor, Instruction Set Architecture: CISC and RISC instruction set architecture, Basic Embedded Processor/Microcontroller Architecture, DSP Processors, PIC, designing a Single Purpose Processor, Optimization Issues, Introduction to FPGA, Behavior Synthesis on FPGA using VHDL. (10L) **UNIT-II**: Sensors and Signals, Discretization of Signals and A/D Converter, Quantization Noise, SNR and D/A Converter, Arduino Uno, I/O Devices: Timers and Counters, Watchdog Timers, Interrupt Controllers, Serial Communication and Timer, Controller Design using Arduino (10L) **UNIT-III:** Power Aware Embedded System, SD and DD Algorithm, Parallel Operations and VLIW, Code Efficiency, DSP Application and Address Generation Unit (5L) **UNIT-IV**: Real Time OS, RMS Algorithm, EDF Algorithm and Resource Constraint Issue, Priority Inversion and Priority Inheritance Protocol (5L) **UNIT-V**: Modelling and Specification, FSM, State chart and Statemate Semantics, Program State Machines, SDL, Data Flow Model, Hardware Synthesis, Scheduling, Case study: Digital camera design. (7L) **UNIT-VI**: HW-SW Partitioning, Optimization, Simulation, Formal Verification. (5L)
Text Books, and/or reference material	**Text Books:** 9. Embedded System Design: A Unified Hardware / Software Introduction -Frank Vahid, Tony Givargis. 10. Embedded System Design: Modeling, Synthesis and Verification- D.D. Gajski, S. Abdi, A. Gerstlauer, G. Schirner **Reference Books:** 9. Embedded System Design- Peter Marwedel.