B.Tech. in Computer Science and Engineering (171 credits)

SEMESTER -1

Sl no	Course Code	Subjects	Credits	L-T-P
1	EE101	Fundamentals of Electrical and Electronics	4	3-0-2
2	PH101	Engineering Physics	4	3-0-2
3	MA101	Engineering Mathematics	4	3-1-0
4	EE102	Engineering Design Principles	3	2-0-2
5	CS101	Principles of Computer Programming	4	3-0-2
6	HS101	Freshman Skills	2	2-0-0
7	HS102	Sports and Physical Education	2	0-1-2
		Total	**23 Credits**	

SEMESTER -2

Sl no	Course Code	Subjects	Credits	L-T-P
1	EE103	Digital Electronics	4	3-0-2
2	MA102	Probability and Statistics	4	3-1-0
3	CS102	Data Structures	4	3-0-2
4	EE104	Hardware Workshop	3	1-0-4
5	CS103	Object Oriented Programming	4	3-0-2
6	HS103	Ecology and Environment Sciences	2	2-0-0
7	CS104	Mobile Application Technologies	2	0-1-2
		Total	**23 credits**	
	MO-1 (Optional)		2/3-0-0	

EXIT AFTER YEAR – 1 → **Certificate in Engineering Sciences (46 credits)**

SEMESTER -3

Sl no	Course Code	Subjects	Credits	L-T-P
1	HS201	Indian Culture, Ethics and Moral Values	2	2-0-0
2	CS201	Discrete Structures	4	3-1-0
3	CS202	Computer Organization and Architecture	4	3-0-2
4	CS203	Design and Analysis of Algorithms	4	3-0-2
5	CS204	Database Systems	4	3-0-2
6	CS205	Paradigms of Programming Languages	4	3-0-2
		Total	**22 credits**	

SEMESTER -4

Sl no	Course Code	Subjects	Credits	L-T-P
1	HS202	Entrepreneurship and Innovation	2	2-0-0
2	CS206	Theory of Computation	3	3-0-0
3	CS207	Operating Systems	4	3-0-2
4	CS208	Computer Networks	4	3-0-2
5	CS209	Mathematical Foundations of Computing	4	3-1-0
6	CS210	Software Engineering	4	3-0-2
		Total	**21 credits**	
	MO-2 (Optional)		2/3-0-0	

EXIT AFTER YEAR - 2 → **Diploma in Computer Science and Engineering (89 credits)**

SEMESTER -5

Sl no	Course Code	Subjects	Credits	L-T-P
1	MS301	Business Economics	3	3-0-0
2	CS0XX	Department Elective-1	3	3-0-0
3	EE303	Microprocessor and Interfacing	4	3-0-2
4	CS301	Compiler Design	4	3-0-2
5	CS302	Computer Graphics	4	3-0-2
6	CS303	Trustworthy Artificial Intelligence	4	3-0-2
		Total	**22 credits**	

Colloquium of 3 credits in summer semester (MOOC, NPTEL etc. in lieu of colloquium)

SEMESTER -6

Sl no	Course Code	Subjects	Credits	L-T-P
1	ENXXX	Art of Engineering Research	2	2-0-0
2		Multidisciplinary/Open Elective- 1/MOOC 1	3	3-0-0
3	CS0XX	Department Elective-2	3	3-0-0
4	CS305	Optimization Techniques	4	3-1-0
5	CS306	Machine Learning	4	3-0-2
6	CS307	Information Security Systems	4	3-0-2
		Total	**20 credits**	

EXIT AFTER YEAR - 3 → **BSc in Computer Science and Engineering (131 credits)**

SEMESTER -7

Sl no	Course Code	Subjects	Credits	L-T-P
1		Multidisciplinary/Open Elective- 2/MOOC 2	3	3-0-0
2	CS0XX	Department Elective -3	3	3-0-0
3	CS401	Natural Language Processing	4	3-0-2
4	CS402	Digital Image Processing	4	3-0-2
5	CS403	Cloud Computing	4	3-0-2
6	CS404	Big Data Analytics	4	3-0-2
7	CS498	Colloquium (Based on industrial training)/MOOC	3	0-0-6
		Total	**25 credits**	

SEMESTER -8

Sl no	Course Code	Subjects	Credits	L-T-P
1	CS499	BTech Project/Internship	12	0-0-24
2		Multidisciplinary/Open Elective- 3/MOOC 3	3	3-0-0
		Total	**15 credits**	

FINAL EXIT AFTER YEAR – 4 → **BTech. In Computer Science and Engineering (171 credits)**

Courses for the Minor in CSE (Total 23 credits required)

Sl no.	Subject	Code	L-T-P	Credits
1	Design and Analysis of Algorithms	CS203	3-0-2	4
2	Database Systems	CS204	3-0-2	4
3	Operating Systems	CS207	3-0-2	4
4	Computer Networks	CS208	3-0-2	4
5	Software, System Analysis and Design	CS0XX	3-0-2	4
6	CSE Elective Course	CS0XX	3-0-0	3

NOTE:

A candidate from CSE can receive a Minor Degree in EEE/Mathematics & Scientific Computing if he/she earns the prescribed credits (Over and above) the credits prescribed by the respective major programme.

A Minor in Computer Science is open to student(s) from other discipline subject to successful completion of the above credits with a minimum of 6 CGPA. A student can opt for the courses depending on the convenience. For example: CS207 and CS210 are offered in 4th semester. A student can opt for these courses along with his regular courses in 4th semester OR he can take one of the two courses in 4th semester and the other in his 6th semester. This reduces the credit load in a particular semester. In addition, if a given course is floated in summer semester, the student can also opt for the same in summer semester.

B.Tech (CSE) Department Elective Courses

Sl no.	Subject	Code	L-T-P	Credits
1	Graph Theory	CS001	3-0-0	3
2	Software, System Analysis and Design	CS002	3-0-2	4
3	Digital Signal Processing	CS003	3-0-0	3
4	Data Analytics and Visualisation	CS004	3-0-0	3
5	Cryptography and Network Security	CS005	3-0-0	3
6	Control System Engineering	CS006	3-0-0	3
7	System Simulation and Modeling	CS007	3-0-0	3
8	IoT Protocols	CS008	3-0-0	3
9	Game Programming	CS009	3-0-0	3
10	Formal languages and Automata	CS010	3-0-0	3
11	Advanced Network Technologies	CS011	3-0-0	3
12	Empirical Techniques in Software Engineering	CS012	3-0-0	3
13	Digital Water Marking and Steganalysis	CS013	3-0-0	3
14	Deep Learning	CS014	3-0-0	3
15	Blockchain Technology	CS015	3-0-0	3
16	Introduction to Robotics	CS016	3-0-0	3
17	Stochastic Processes and Queuing Theory	CS017	3-0-0	3
18	Advanced Competitive Programming	CS018	3-0-0	3
19	Network Programming	CS019	3-0-0	3
20	Combinatorial Mathematics	CS020	3-0-0	3
21	Network Design and Optimization	CS021	3-0-0	3
22	Software reliability	CS022	3-0-0	3

23	Computer Vision	CS023	3-0-0	3
24	Recommender Systems	CS024	3-0-0	3
25	Modern Cryptography	CS025	3-0-0	3
26	Robot Motion Planning	CS026	3-0-0	3
27	Nature Inspired Computing	CS027	3-0-0	3
28	Game Theory and Applications	CS028	3-0-0	3
29	Human – Computer Interaction	CS029	3-0-0	3
30	Randomized Algorithms	CS030	3-0-0	3

CODE WITH CSxxx

1	**Code of the subject**	CS101
2	**Title of the subject**	Principles of Computer Programming
3	**Prerequisite**	No
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand the basic principles of programming languages. To provide design & development of C and Python programming skills. To introduce problem solving methods and program development.
6	**Brief Contents**	Basics of Computer Languages C, Compilers, Interpreter, Programming Environments and Debugging: types of errors and debugging techniques. Programming features: Data types, Expressions and Operators, Control statements, Iterations. Functions: Scope of variables, call by value, call by reference, Recursion, Pointers. Array, String, Structures and Unions. File handling, File redirection, File pointers. Applications of C programming concepts in different data structures. Python: Introduction, Program Organization, Functions, Modules and Libraries.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text/references**	1. Kernighan, B.W. and D. M. Ritchie (1998): The C programming language, 2nd ed. Prentice Hall of India. 2. Kanetkar, Y (2016): Let us C, 15thed .BPB Publications. 3. King K.N (2008): C Programming: A Modern Approach. 2nd ed. W. W. Norton & Company.

1	**Code of the subject**	CS102
2	**Title of the subject**	Data Structures
3	**Prerequisite**	Principles of Computer Programming
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand the basic data structures and algorithms for performing operations on data structures, the use of data structures to provide efficient software solutions, and some algorithm paradigms for building efficient algorithms.
6	**Brief Contents**	Introduction to Abstract data types, linear and linked data structures – Arrays, Stacks, Queues, Linked List. Introduction to searching and sorting algorithms –Quick sort, Merge sort, Heap sort, linear time sorting; evaluation of infix/postfix expressions. Trees, binary search trees and basic operations, AVL trees, heaps, hash tables. Algorithm analysis: time and space complexity, asymptotic behavior, estimating runtime, comparison of algorithms. Graphs and basic algorithms on graphs: depth first and breadth first search, Dijkstra‘s algorithm. Hash Tables
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications

8	**Text/references**	1. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. 2009. Introduction to Algorithms, Third Edition (3rd ed.). The MIT Press. 2. Steven S. Skiena. 2008. The Algorithm Design Manual (2nd ed.). Springer Publishing Company, Incorporated.

1	**Code of the subject**	CS103
2	**Title of the subject**	Object Oriented Programming
3	**Prerequisite**	Programming concepts
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To develop programming skill and to solve engineering related
6	**Brief Contents**	Object oriented thinking: Need for OOP Paradigm, Procedural programming vs object oriented programming, object oriented concepts. Class and object concepts: Difference between C structure and class, specifying a class, Defining members inside and outside class, etc. Constructor and destructor concepts, Operator overloading and Type Conversion, Inheritance and polymorphism concepts Working with files: Classes for file stream operations, opening and closing files, File opening modes, file Pointers, Error handling during file operations, command line arguments. Templates: Class template, class template with parameter, function template, function template with parameter and Exception handling
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**List of text books/references**	1. HM Deitel and PJ Deitel ―C++ How to Program, Seventh Edition, 2010, Prentice Hall. 2. Brian W. Kernighan and Dennis M. Ritchie, ―The C programming Language, 2006, Prentice-Hall. 3. E Balagurusamy, ―Object oriented Programming with C++, Third edition, 2006, Tata McGraw Hill. 4. Bjarne Stroustrup, ―The C++ Programming language, Third edition, Pearson Education. 5. Horstmann ―Computing Concepts with C++ Essentials,Third Edition,2003, John Wiley. 6. Robert Lafore, ―Object Oriented Programming in C++, 2002, Pearson education.

1	**Code of the subject**	CS104
2	**Title of the subject**	Mobile Application Technologies
3	**Prerequisite**	No
4	**L-T-P**	0-1-2
5	**Learning Objectives**	To develop the basic skills of using Android IDE and Android SDK for implementing Android applications
6	**Brief Contents**	Introduction, UX development, Testing and debugging of front end and back end application components and their interaction. .
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications

8	**Text /references**	1. Android Programming: The Big Nerd Ranch Guide 4th Edition, Bill Phillips, Brian Hardy 2. The Busy Coder's Guide to Android Development, Mark Murphy.

1	**Code of the subject**	CS201
2	**Title of the subject**	Discrete Structures
3	**Prerequisite**	Engineering Mathematics
4	**L-T-P**	3-1-0
5	**Learning Objectives**	To prepare for a background in abstraction, notation, and critical thinking for the mathematics most directly related to computer science. To foster rigorous thinking skills that can enhance the quality of work of computing professionals. To relate and apply these concepts to practical applications of computer science.
6	**Brief Contents**	Fundamentals of Logicand their use in program proving, resolution principle. Set Theory and Functions, Graph Theory, Group Theory, Elementary Combinatorics etc.
7	**Text/references**	1.Bernanrd Kolman, Robert C Busby, S.Ross, Discrete Mathematical Structures, PHI Learning 2. Kenneth H. Rosen, Discrete Mathematics and Its Appications, Tata McGraw-Hill Edition 3. I.N. Herstein, Topics in Algebra, John Wiley Publications 4. Ralph P. Grimaldi, B.V. Ramana, Discrete and Combinatorial Mathematics, Pearson Education

1	**Code of the subject**	CS202
2	**Title of the subject**	Computer Organisation and Architecture
3	**Any prerequisite**	Digital Electronics, Principles of computer programming
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand the Organization and architecture aspects of
6	**Brief Contents**	Basic functional blocks of a computer, introduction to Instruction set architecture of a CPU and instruction sets of some common CPUs. Data representation, Computer arithmetic, Control unit design, Memory system, Peripheral devices and their characteristics, Performance enhancement techniques Pipelining, Memory organization.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text/references**	1. Computer Organization and Design: The Hardware/Software Interface, David A Patterson, John L. Hennessy, 4th Edition, Morgan Kaufmann. 2. Computer Architecture and Organization by William Stallings, PHI Pvt. Ltd., Eastern Economy Edition.

1	**Code of the subject**	CS203
2	**Title of the subject**	Design and Analysis of Algorithms
3	**Prerequisite**	Data Structures, Principles of Computer Programming, Engineering Mathematics
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand the performance aspects of algorithms in programming the computing systems
6	**Brief Contents**	Introduction, Asymptotic complexity, Searching in list, Concepts of graphs and shortest path estimation algorithms, Divide and conquer approaches, Search Trees, Greedy : Interval scheduling, Greedy :Proof strategies,Greedy : Human coding, Dynamic Programming: weighted interval scheduling Dynamic Programming, Intractability: NP completeness, Intractability :reductions and examples
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text/references**	1. Introduction to Algorithms (Eastern Economy Edition) by Thomas H Cormen and Charles E Leiserson. 2. Design and Analysis of Algorithms by S Sridhar. 3. Design and Analysis of Computer Algorithms by AHO.

1	**Code of the subject**	CS204
2	**Title of the subject**	Database Systems
3	**Prerequisite**	
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand a Database application, the design and performance aspects from the perspective of Database systems of the past, present and future.
6	**Brief Contents**	Introduction to Databases, Relational Data Model, Relational Algebra, SQL and NoSQL concepts, Database Normalization, Indexing, Database Transactions, Recovery Systems, Transaction Schedules, Concurrency Control, Query Processing and Query Optimization.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. Abraham Silberschatz, Henry Korth, and S. Sudarshan. Database Systems Concepts (5ed.). McGraw-Hill, New York, USA. 2. Ramez A. Elmasri, Shankrant B. Navathe. Fundamentals of Database Systems Addison-Wesley Longman Publishing Co. 3. Paul DuBois. Mysql. New Riders Publishing 4. C. J. Date. Database in Depth: Relational Theory for Practitioners. O'Reilly Media, Inc. 5. Bipin C. Desai. An Introduction to Database Systems. West Publishing Co.

1	**Code of the subject**	CS205
2	**Title of the subject**	Paradigms of Programming Languages
3	**Prerequisite**	Principles of Computer Programming, Object Oriented Programming
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand the key principles of programming language paradigms, compare and contrast the advantages and disadvantages of the imperative and functional programming paradigms, describe the compilation principles and highlight modern trends' impact on programming languages.
6	**Brief Contents**	The role and for programming languages, characteristics; Programming language paradigms, Language designand translation issues; Properties of data types and objects, type conversion, binding and binding times. Procedures Sequence Control, Subprogram control, desirable and undesirable characteristics of procedural programming. Case study of Pascal. Functional Programming Paradigm, Declarative Programming Paradigm, Parallel Programming Paradigm, Classification of computer architectures, principles of parallel programming, precedence graph, data parallelism, control parallelism, message passing, shared address space, synchronization mechanisms, mapping, granularity, compilers, operating systems; Additional Programming Paradigms Data flow programming design principles, Database programming design principles, Network programming design principles, Socket programming in JAVA, Internet programming design principles etc.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text/references**	1. RoostaSeyed, “Foundations of Programming Languages Design & Implementation”, Cenage learning. 2. Pratt T.W., Zelkowitz “Programming Languages: Design and Implementation” PHI 3. Programming Language Design Concepts, D. A. Watt, Wiley India Edition. Reference Books: 1. Sebesta R. W., “Concepts of programming languages”, Pearson Education 2001, 4th edition. 2. Sethi Ravi, “Programming Languages: Concepts and Constructs” Pearson Education, 3. Herbert Schildt “The Complete Reference Java2”, 5th edition, Tata McGraw Hill.

1	**Code of the subject**	CS206
2	**Title of the subject**	Theory of Computation
3	**Prerequisite**	No
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To introduce the mathematical foundations of computation, develop the ability to understand and conduct mathematical proofs for computation and algorithms.

6	**Brief Contents**	Finite Automata, Finite State system concepts, Regular Languages, Equivalence of NFA and DFA, Minimization of DFA- – Pumping Lemma for Regular. Grammars, Pushdown Automata, Turing Machines, Unsolvable Problems and Computable functions, Measuring and classifying complexity: Tractable and Intractable problems- Tractable and possibly intractable problems – P and NP completeness – Polynomial time reductions.
7	**Text /references**	1. Hopcroft J.E., Motwani R. and Ullman J.D, ―Introduction to Automata Theory, Languages and Computations, Pearson Education. 2. John C Martin, ―Introduction to Languages and the Theory of Computation, TMH, New Delhi. REFERENCES 1.Mishra K L P and Chandrasekaran N, ―Theory of Computer Science – Automata, Languages and Computation, Third Edition, Prentice Hall of India 2.Harry R Lewis and Christos H Papadimitriou, ―Elements of the Theory of Computation, Second Edition, Prentice Hall of India, Pearson Education, New Delhi. 3.Peter Linz, ―An Introduction to Formal Language and Automata, Third Edition, Narosa Publishers. 4.KamalaKrithivasan and Rama. R, ―Introduction to Formal Languages, Automata Theory and Computation, Pearson Education.

1	**Code of the subject**	CS207
2	**Title of the subject**	Operating Systems
3	**Prerequisite**	Computer Organization; Data Structures and Computer Programming
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To study the importance of the operating system and its function, techniques of the operating system to achieve its goals as resource manager. Application interaction with the operating system and the operating systems interaction with the machine.
6	**Brief Contents**	Introduction and history of Operating systems, Process concepts and scheduling, Storage management, Processor management, Interprocess communication, CPU scheduling, Process Synchronization, Memory Management, Virtual memory concepts, Deadlocks, Device management, File management, File Systems, Free space Management: Bit vector, Linked list. Some case Studies of traditinal and modern operating systems.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. A. Silberschatz & P.B. Galvin, Operating System concepts and principles, Wiley India. 2. A. Tanenbaum, Modern Operating Systems‘, Prentice Hall India 3. W. Stallings, _Operating Systems: Internals and design Principles, Pearson Ed.

		4. M.J. Bach, Design of Unix Operating system', Prentice Hall. Additional Reading: 1. D.M. Dhamdere, Operating Systems: a concept based approach', Tata McGraw-Hill Pubs. 2. G. Glass, Unix for programmers and users-a complete guide, Pearson Ed.

1	**Code of the subject**	CS208
2	**Title of the subject**	Computer Networks
3	**Prerequisite**	User applications and some aspects of process and their interaction
4	**L-T-P**	3-0-2
5	**Learning Objectives**	The understand the purpose and overview of the Internetworking technology, issues, and approaches using top-down philosophy.
6	**Brief Contents**	Computer Networks and the Internet, Network Application Architectures, Processes Communication, Transport Services, Application-Layer Protocols, The Web and HTTP, Case Study: P2P Internet Telephony with Skype, Socket Programming with TCP and UDP; Transport Layer: Relationship Between Transport and Network Layers, Overview of the Transport Layer in the Internet, Principles of Reliable Data Transfer Services, Multiple Access protocols, Link-Layer concepts; Wireless and Mobile Networks, Cellular Internet Access, Mobile IP.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	Computer Networking: A top-down approach featuring the Internet / James F. Kurose , Keith W. Ross., 7th edition, Pearson.

1	**Code of the subject**	CS209
2	**Title of the subject**	Mathematical Foundations of Computing
3	**Prerequisite**	Nil
4	**L-T-P**	3-1-0
5	**Learning Objectives**	To model computer science domain problems mathematically, think abstractly and employ techniques to study the properties.
6	**Brief Contents**	Induction, Propositional predicate logic, First order logic, Proof techniques and applications, Linear programming, Series divergence/convergence, Fourier Series/Transform, number theory etc.
7	**Text /references**	1. Donald F. Stanat and David F. McAllister, Discrete mathematics in Computer Science. 2. Thomas Koshy, Elementary number theory with Applications, Elsevier 3. I. N. Herstein, Topics in Algebra. JOHN Wiley & SONS. 4. Simulyan, First Order Logic

1	**Code of the subject**	CS210
2	**Title of the subject**	Software Engineering
3	**Prerequisite**	
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To impart software engineering concepts helpful for designing software systems for standalone and networked applications.
6	**Brief Contents**	Introduction, Software development process, project management process. Software requirement Analysis and specification; Software planning, Software design, Verification and validation techniques, Software quality and reliability, System Reliability and Reliability measures
7	**Contents for lab**	Use of software design tools (UML etc.) for design, software applications design and testing on vrious application centric measures, Fintech software design etc.
8	**Text /references**	1. Pham, Hoang. System software reliability. Springer Science & Business Media, 2007. 2. Jalote Pankaj, An Integrated Approach to Software Engineering, Narosa Publishing House 3. Pressman, Roger S., Software Engineering : A practitioner‘s Approach, McGraw-Hill, Inc.

1	**Code of the subject**	CS301
2	**Title of the subject**	Compiler Design
3	**Prerequisite**	Theory of Computation
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To design the front end of the compiler, scanner, parser, intermediate code generator, objectcode generator, and the parallel compilation strategies. To gain the ability to implement a parser etc.
6	**Brief Contents**	The structure of Compiler – Lexical analysis, Syntax analysis, LR parsers; Intermediate code generation concepts, Object code generation, Code optimization, Parallelizing compiler etc.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. Alfred V. Aho, Monica S.Lam, Ravi Sethi, Jeffrey D.Ullman, Compilers : Principles, Techniques and Tools, Second Edition, Pearson Education. 2. Randy Allen, Ken Kennedy, Optimizing Compilers for Modern Architectures: A Dependence-based Approach, Morgan Kaufmann Publishers. 3. Steven S. Muchnick, Advanced Compiler Design and Implementation‖, Morgan Kaufmann Publishers - Elsevier Science, India, Indian Reprint. 4. Keith D Cooper and Linda Torczon, Engineering a Compiler, Morgan Kaufmann Publishers Elsevier Science. 5. V. Raghavan, Principles of Compiler Design, Tata McGrawHill Education Publishers.

1	**Code of the subject**	CS302
2	**Title of the subject**	Computer Graphics
3	**Prerequisite**	
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To expose onto the primary tools by which the flood of information from Computational Science is analyzed.
6	**Brief Contents**	Introduction of computer graphics, Graphic Displays and the algorithms; Three Dimensional aspects of graphics; Transformations; Windowing and Clipping concepts; Hidden Lines and Surfaces etc.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**List of text books/references**	1.Computer Graphics, C Version Donald D Hearn, M. Pauline Baker 2. Computer Graphics: Principles and Practiceby James D. Foley, Andries van Dam , Steven K. Feiner

1	**Code of the subject**	CS303
2	**Title of the subject**	Trustworthy Artificial Intelligence
3	**Prerequisite**	
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand the techniques and concepts related to machine based reasoning systems through various applications of AI
6	**Brief Contents**	Introduction to AI and intelligent agents. Problem solving methods in AI, Informed and uninformed search strategies, knowledge representation, Uncertain Knowledge and Reasoning, Probabilities, Bayesian Networks. Overview of different forms of learning, Learning Decision Trees, Artificial Neural Networks and Fuzzy Approaches; Logic in AI, Prolog, Modern AI language and tools etc.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 2nd Ed, Prentice Hall, 2003 2. Elaine Rich and Kevin Knight. Artificial Intelligence, Tata McGraw Hill Reference Books: 1. Patrick Henary Winston, Artificial Intelligence, Pearson publication 2. Deepak Khemani. A First Course in Artificial Intelligence, McGraw Hill Education (India) 3. Eugene Charnaik and Drew McDermott, Introduction to Artificial Intelligence, Pearson publication 4. Nils John Nilsson, The Quest for Artificial Intelligence: A History of Ideas and Achievements, Morgan Kaufman 5. Dennis Rothman, Artificial Intelligence by Example

1	**Code of the subject**	CS305

2	**Title of the subject**	Optimization Techniques
3	**Prerequisite**	Engineering mathematics, programming
4	**L-T-P**	3-1-0
5	**Learning Objectives**	To equip with the engineering problem formulation skills and optimization approaches to solve the problems along with quantitative analysis of those.
6	**Brief Contents**	Types of OR models, linear programming, problem formulation, graphical solution, simplex method, artificial variables techniques, two–phase method, big-M method etc. Transportation and assignment problems, Sequencing and Replacement, Theory of games and inventory, Dynamic Programming, engineering applications.
7	**List of text books/references**	1. J. K. Sharma, "Operations Research", Macmillan, 5th Edition, 2012. 2. R. Pannerselvan, "Operations Research", 2nd Edition, PHI Publications, 2006

1	**Code of the subject**	CS306
2	**Title of the subject**	Machine Learning
3	**Prerequisite**	Linear Algebra
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To understand popular ML algorithms with their associated mathematical foundations and use them for solving real world problems as machine learning tasks
6	**Brief Contents**	Introduction and Fundamentals of ML. Selected Algorithms - Ensembling and RF, Linear SVM, K Means,Logistic Regression, Naive Bayes etc. Neural Network Learning - Role of Loss Functions and Optimization, Gradient Descent and Perceptron/Delta Learning, MLP, Backpropagation, MLP for Classification and Regression, Regularisation, Early Stopping. Kernels (with SVM), Bayesian Methods, Generative Methods, HMM, EM, PAC learning. Introduction to Deep Learning, CNNs, Popular CNN Architectures, RNNs, GANS and Generative Models, Advances in Backpropagation and Optimization for Neural Networks Adversarial Learning
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press 2. Tom M. Mitchell, Machine Learning - McGraw Hill Education, International Edition 3. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly Media, Inc. 2nd Edition 4. Ian Goodfellow, Yoshoua Bengio, and Aaron Courville, Deep Learning MIT Press Ltd, Illustrated edition 5. Christopher M. Bishop, Pattern Recognition and Machine Learning - Springer, 2nd edition

		6. Trevor Hastie, Robert Tibshirani, and Jerome Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction - Springer, 2nd edition

1	**Code of the subject**	CS307
2	**Title of the subject**	Information Security Systems
3	**Prerequisite**	
4	**L-T-P**	3-0-2
5	**Learning Objectives**	This course provides a comprehensive study of the security principles and practices of information systems. Helps build a good understanding of the foundational theory behind computer security and the threats.
6	**Brief Contents**	Security issues in computing, communications, and electronic commerce. Goals and vulnerabilities; legal and ethical issues; basic cryptology; private and authenticated communication; electronic commerce; software security; viruses and other malicious code; operating system protection; trusted systems design; network security; firewalls; policy, administration and procedures; auditing; physical security; disaster recovery; reliability; content protection; privacy.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. William Stallings and Lawrie Brown. 2014. Computer Security: Principles and Practice (3rd ed.). Prentice Hall Press, Upper Saddle River, NJ, USA. 2. Behrouz A. Forouzan. 2007. Cryptography & Network Security 3. M. Stamp, Information Security: Principles and Practice, Wiley 4. M. E. Whitman and H. J. Mattord, Principles of Information Security.

1	**Code of the subject**	CS401
2	**Title of the subject**	Natural Language Processing
3	**Prerequisite**	AI and ML
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To equip the learners with fundamental and advanced aspects of NLP applications.
6	**Brief Contents**	Human language processing paradigms; Phases in natural language processing, applications. Text representation in computers, encoding schemes. Introduction to corpus, elements in balanced corpus, TreeBank, PropBank, WordNet, VerbNet etc. Resource management with XML, Management of linguistic data with the help of GATE, NLTK. Regular expressions, Finite State Automata, word recognition, lexicon. Morphology, acquisition models, Finite State Transducer. N-grams, smoothing, entropy, HMM, ME, SVM, CRF.

		Speech tagging. Review of natural language grammars, lexeme, phonemes, phrases and idioms, word order, agreement, tense, aspect and mood and agreement, Context Free Grammar, spoken language syntax. Parsing, Word Sense Disambiguation, Discourse- Reference resolution etc. Applications of NLP, Summarization Information, Machine Translation overview.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. Daniel Jurafsky and James H Martin, Speech and Language Processing: An introduction to Natural Language Processing, Computational Linguistics and Speech Recognition, Prentice Hall, 2nd Edition, 2008.

1	**Code of the subject**	CS402
2	**Title of the subject**	Digital Image Processing
3	**Prerequisite**	Mathematics
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To introduce the basic concepts of Digital image processing with emphasis on applications in various field of recent research.
6	**Brief Contents**	Introduction and Fundamentals, Image Enhancement in Spatial Domain, Image Enhancement in Frequency Domain, Image Restoration, Segmentation, Representation and Description.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1.Digital Image Processing 2nd Edition, Rafael C. Gonzalvez and Richard E. Woods. Published by: Pearson Education. 2.R.J. Schalkoff ,Digital Image Processing and Computer Vision John Wiley and Sons, NY. 3. William K. Prat, Digital Image Processing, John Wiley and Sons, NY

1	**Code of the subject**	CS403
2	**Title of the subject**	Cloud Computing
3	**Any prerequisite**	Computer Networks, OS, Software engineering, Distributed Computing
4	**L-T-P**	3-0-2
5	**Learning Objectives**	To equip with the enabling technology for an on-demand access to a shared pool of configurable computing resources. To introduce various aspects of cloud computing paradigm and future research trends.
6	**Brief Contents**	Introduction to Cloud Computing, Introduction to Parallel and Distributed Computing, Cloud Computing Architecture, Service Management, Data Management in Cloud Computing, Virtualization & Resource Management, Cloud Security, Open Source and Commercial Clouds, Cloud Simulator, Research trend in Cloud Computing, Fog Computing.

7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. Cloud Computing: Principles and Paradigms, Editors: RajkumarBuyya, James Broberg, Andrzej M. Goscinski, Wiley 2. Enterprise Cloud Computing - Technology, Architecture, Applications, Gautam Shroff, Cambridge University Press 3. Cloud Computing Bible, Barrie Sosinsky, Wiley-India 4. Cloud Security: A Comprehensive Guide to Secure Cloud Computing, Ronald L. Krutz, Russell Dean Vines, Wiley

1	**Code of the subject**	CS404
2	**Title of the subject**	Big Data Analytics
3	**Prerequisite**	
4	**L-T-P**	3-0-2
5	**Learning Objectives**	Understanding of core concepts behind big data problems, applications, systems and the techniques along with an introduction to some of the most common Big Data frameworks and Big Data Streaming Platforms.
6	**Brief Contents**	Introduction to Big Data, Enabling Technologies for Big Data, Big Data Stack, Big Data distribution packages. Big Data Platforms, Overview of Apache Spark, HDFS, YARN, Introduction to MapReduce, MapReduce Programming Model with Spark, MapReduce Example: Word Count, Page Rank etc. Introduction to Big Data Storage Platforms for Large Scale Data Storage, CAP Theorem, Eventual Consistency, ACID and BASE, Zookeeper and Paxos, Cassandra, HBase Big Data Streaming Platforms for Fast Data, Big Data Streaming Systems, Big Data Pipelines for Real-Time computing, Spark Streaming, Kafka, Streaming Ecosystem. Introduction to Big Data Applications (Machine Learning), Overview of Big Data Machine Learning, Mahout, Big Data Machine Learning Algorithms in Mahout- kmeans, Naïve Bayes etc. Introduction of Big Data Machine learning with Spark, Big Data Machine Learning Algorithms in Spark- Introduction to Spark MLlib, Introduction to Deep Learning for Big Data. Introduction to Big Data Applications (Graph Processing), Introduction to Pregel, Introduction to Giraph, Introduction to Spark GraphX.
7	**Contents for lab**	Experiments are based on the theoretical contents and their applications
8	**Text /references**	1. Big Data Science & Analytics: A Hands-On Approach, Arshdeep Bahga and Vijay Madisetti, VPT. 2. The Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics, Bill Franks, Wiley. 3. Big Data Analytics: Disruptive Technologies for Changing the Game, ArvindSathi, MC Press. 4. Hadoop: The Definitive Guide, Tom White, O'Reilly.

1	**Code of the subject**	CS498
2	**Title of the subject**	Colloquium (Based on industrial training)/ MOOC
3	**Prerequisite**	
4	**L-T-P**	0-0-6
5	**Learning Objectives of the subject**	To instill the ability to identify skills and gain practical work experience To provide an opportunity to observe and contribute in the workplace To take ownership and responsibility of a project assignment, given by a designated manager/supervisor To provide networking opportunities with other members of the organization To offer performance feedback and mentorship throughout the internship
6	**Brief Contents**	An internship helps you train under experienced professionals and explore what your chosen career path would be like, and an internship with a company in your field can help you to develop the skills you require to thrive within a professional setting. At the end of the training period, the company may ask you to review your time with them and write a report based on your experience. In addition, hone the skills needed to develop internship report.
7	**Contents for lab**	There are no specific laboratory sessions for this. However, this being a completely practical oriented course, the student has to devote significant time to achieve the objectives.
8	**Text /references**	1. https://www.careereducation.columbia.edu/resources/10-tips-make-most-internship 2. https://in.indeed.com/career-advice/career-development/internship-report

1	**Code of the subject**	CS499
2	**Title of the subject**	BTech Project/ Internship
3	**Any prerequisite**	
4	**L-T-P**	0-0-24
5	**Learning Objectives**	To develop deeper knowledge, understanding, capabilities and attitudes in the context of the programme of study.
6	**Brief Contents**	The purpose of this course is to enable the student to develop deeper knowledge, understanding, capabilities and attitudes in the context of the programme of study. The student is expected to demonstrate the abilities of the major subject/field of study, including deeper insight into hardware/software application development work. Develop the capability to create, analyse and critically evaluate different technical/architectural solutions. Equip with the needed skills to clearly present and discuss theconclusions as well as the knowledge and arguments that form the basis for the learning outcome in written and spoken English. Importantly it is necessary to march on the ethical aspects of research and development work.
7	**Contents for lab**	There are no specific laboratory sessions for this. However, this being a completely practical oriented course, the student has to devote significant time to achieve the objectives.

8	**List of text books/references**	https://grad.wisc.edu/wp-content/uploads/sites/329/2018/02/2018-Project-Management-for-Graduate-Students-Course-Workbook.pdf

1	**Code of the subject**	CS001
2	**Title of the subject**	Graph Theory
3	**Prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To teach the applications of game theory, auction and equilibrium.
6	**Brief Contents**	Introduction to Game Theory, Dominant Strategies and Nash Equilibrium, Alternate Strategies: Maximin, Maximax, and Minimax Regret Solvability, N-Player Games, Mixed Strategy Nash Equilibria, Subgame Perfection in Discrete Choice Games, Continuous Games and Imperfect Competition, Infinitely Repeated Games, Tacit Collusion: An application of Infinites Repeated Games, imperfect Information: Simultaneous-play, ayesian Games, Applications of Bayesian Games: Auctions and Voting, Cournot's Duopoly with Imperfect Information 3.Radio Spectrum, With Arbitrary Distribution of Valuations, Extensive Form Game with Perfect Information, Stackelberg Model of Duopoly, Buying Votes, Committee Decision-Making, Repeated games, The Prisoner's Dilemma, General Result, Supermodular Game and Potential Game, Supermodular Game and Potential Game, Wireless Networks: Resource Allocations, Admission Control, Routing in Sensor and Ad-Hoc Networks, Modeling Network Traffic and Strategic Network Formation, Rubinstein Bargaining Model with Alternating Offers, Nash Bargaining Solution, Relation of Axiomatic and Strategic Model, Auction and Mechanism Design with Applications, Revenue Equivalence, Risk Averse Bidders, Asymmetries among Bidders, Mechanism, Optimal Mechanism.
7	**Contents for lab**	NA
8	**Text books/references**	1. Martin Osborne, An Introduction to Game Theory, Oxford University Press, 2003 2. Prajit Dutta, Strategies and Games, MIT Press. 3. K H Ericson, Game Theory, Createspace Independent Publishing Platform.

1	**Code of the subject**	CS002
2	**Title of the subject**	Software, System Analysis and Design
3	**Any prerequisite**	No
4	**L-T-P**	3-0-0
5	**Learning Objectives of the subject (in about 50 words)**	1. Outline the software design process, and demonstrate how the essential design principles are applied within it. 2. Illustrate the essential elements of software structure and architecture in terms of styles, patterns and families of programs and frameworks. 3. Demonstrate the application of quality analysis and evaluation principles.

		4. Employ function, object, data-structure and component-based design methodologies in a typical software design project.
6	**Brief Contents**	1. Software Design Fundamentals: General design concepts, Context of software design, Software design process, Software design principles. 2. Key Issues in Software Design: Concurrency, Control and handling of events, Data persistence, Distribution of components, Error exception handling and fault tolerance, Interaction and presentation, Security. 3. Software Structure and Architecture: Architectural structures and viewpoints, Architectural styles, Design patterns, Architecture design decisions, Families of programs and frameworks 4. User Interface Design: General user interface design principles, User interface design issues, Design of user interaction modalities, Design of information presentation, User interface design process, Localization and internationalization, Metaphors and conceptual models 5. Software Design Quality Analysis and Evaluation: Quality attributes, Quality analysis and evaluation techniques, Measures. 6. Software Design Notations: Structural descriptions (static view), Behavioral descriptions (dynamic view). 7. Software Design Strategies and Methods: General strategies, Function-oriented (structured) design, Object-oriented design, Data structure-oriented design, Component-based design, other methods.
7	**Contents for lab**	Assignments
8	**List of text books/references**	1. Systems Analysis and Design (MindTap Course List) 12th Edition by Scott Tilley, 2019. 2. Head First Design Patterns: Building Extensible and Maintainable Object-Oriented Software 2nd Edition 2nd Edition by Eric Freema. 3. Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems Kindle Edition by Martin Kleppmann.

1	**Code of the subject**	CS003
2	**Title of the subject**	Digital Signal Processing
3	**Prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	In this course, we will mainly study the following topics: signal representation in time domain, Fourier transform, sampling theorem, linear time-invariant system, discrete convolution, z-transform, discrete Fourier transform, and discrete filter design.After this course, the students should be able to understand how to analyse a given signal or system using tools such as Fourier transform and z-transform; how to process signals to make them more useful.

6	**Brief Contents**	Review of Signals and Systems: Discrete time complex exponentials and other basic signals-scaling of the independent axis and differences from its continuous-time counterpart-system properties (linearity, time-invariance, memory, causality, BIBO stability)-LTI systems, convolution, correlation, continuous-time Fourier series and Fourier transform. Sampling: Impulse train sampling and reconstruction, aliasing, A/D and D/A conversion, quantization noise. Discrete-Time Fourier Transform (DTFT): Complex exponentials as Eigen signals of LTI systems-DTFT definition-inversion formula-properties-relationship to continuous-time Fourier series (CTFS). Z-Transform: Generalized complex exponentials as eigensignals of LTI systems-z-transform definition-region of convergence (RoC)-properties of RoC-properties of the z-transform, inverse z-transform methods,pole-zero plots, RoC implications of causality and stability. Frequency Domain Analysis of LTI Systems: Frequency response of systems with rational transfer function, definitions of magnitude and phase response, geometric method of frequency response evaluation from pole-zero plot, frequency response of single complex zero/pole, frequency response of filters. Discrete Fourier Transform (DFT): Definition of the DFT and inverse DFT-circular shift of signal and the ―index mod N‖ concept-properties of the DFT-circular convolution and its relationship with linear convolution—sectioned convolution methods: overlap add and overlap save-effect of zero padding.
7	**Contents for lab**	
8	**Text /references**	1. Discrete-Time Signal Processing by Alan V. Oppenheim and Ronald W. Schafer, 3rd edition, 2010, Prentice Hall, Upper Saddle River, NJ. 2. Digital Signal Processing by SanjitMitra, 4th edition, 2011, McGraw-Hill, New York, NY.

1	**Code of the subject**	CS004
2	**Title of the subject**	Data Analytics and Visualisation
3	**Prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	1. Provide an overview of the statistical tools used to process, analyse, and visualize data. 2. Form testable hypotheses that can be evaluated using common statistical analyses.
6	**Brief Contents**	Introduction to the science of statistics: Fundamental elements of Statistics, Qualitative and Quantitative Data Summaries, Normal distribution, Sampling, Central Limit Theorem. Confidence intervals and hypothesis tests: Statistical Inference, Stating Hypotheses, Test Statistics and p-Values, Evaluating Hypotheses, Significance Tests and Confidence Intervals, Inference about a Population Mean, Two-Sample Problems

		Parametric association: Scatterplots, Correlation, Simple Linear Regression, F-test for Simple Linear Regression, t-test for Simple Linear Regression. Multiple linear regression: Equation of multiple linear regression, Interpretation of multiple linear regression, F-test for Multiple Linear Regression, t-tests in Multiple Linear Regression, Cautions about Regression Analysis of Variance (ANOVA): One-Way Analysis of Variance, F-test for ANOVA, Evaluating Group Differences, Type I and Type II Errors, Issues with Multiple Comparisons, Assumptions of Analysis of Variance, Relationship between One-Way ANOVA and Regression, One-Way Analysis of Covariance, Two-Way Analysis of Variance, Two-Way Analysis of Covariance Analysis for proportions: One-Sample Tests for Proportions, Significance Tests for a Proportion, Confidence Intervals for a Proportion, Two-Sample Tests for Proportions, Confidence Intervals for Differences in Proportions, Significance Tests for Differences in Proportions, Effect Measures, Logistic Regression, Multiple Logistic Regression, Area under the ROC Curve.
7	**Contents for lab**	Implementation of data analytics methods using R or Python.
8	**Text books/references**	1. Andy Field, Jeremy Miles and Zoe Field, "Discovering Statistics Using R", SAGE Publications Ltd (2012). 2. Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani "An Introduction to Statistical Learning with Applications in R", Springer (2013).

1	**Code of the subject**	CS005
2	**Title of the subject**	Cryptography and Network Security
3	**Prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To develop a framework to understand and implement cryptographic aspects. To enhance an ability to analyze a problem, and identify and define the computing requirements for data security. To prepare abstract and critical thinking background for computer science students
6	**Brief Contents**	Module I- Introduction Classical Encryption Techniques: Symmetric Cipher Model, Substitution Techniques, Transposition Techniques, Stream Cipher and Block Cipher, Random Number Generator, One-time Pad. Module II- Finite Field and Number Theory Groups, Rings, Fields, Modular Arithmetic, Euclid's Algorithm, Finite Fields Of Form GF (p) And GF (2n). Polynomial Arithmetic, Prime Numbers, Fermat's And Euler's Theorem, Testing For Primality, The Chinese Remainder Theorem, Discrete Logarithms. Module III-Symmetric Cipher and Public Key Encryption Block Cipher Principles, Data Encryption Standard (DES), Multiple Encryption, Triple DES, Advanced Encryption Standard (AES),

		Principles of Public Key Cryptosystems, The RSA Algorithm, Key Management, Elliptic Curve Arithmetic, Elliptic Curve Cryptography. Module IV-Cryptographic Protocols Authentication Requirement, Authentication Function, MAC, Hash Functions, Security of Hash Function , Digital Signatures, Module V-Network Security and Applications Authentication applications: Kerberos – X.509 Authentication services, Public Key Infrastructure, Pretty Good Privacy, S/MIME IP security: Encapsulating Security Payload (ESP)-Internet Key Exchange (Phases of IKE, ISAKMP/IKE Encoding) Web Security: Web Security Considerations, Secure Socket Layer and Transport layer Security, System Security
7	**Contents for lab**	
8	**List of text books/references**	1. William Stallings, Cryptography and Network security, 4e,Prentice Hall of India, New Jersey, 2008. 2. ChristofPaar, Jan Pelzl, Understanding Cryptography, Springer-Verlang, Berlin, 2010 3. Behrouz A Forouzan, Cryptography and Network security, Tata Mc-Graw Hill, New York, 2007.

1	**Code of the subject**	CS006
2	**Title of the subject**	Control System Engineering
3	**Prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To be able to obtain a working mathematical model of a system. To be able to do time-domain and frequency-domain analyses of the model to predict the system's behaviour. To be able to design control systems that meet design specifications.
6	**Brief Contents**	Introduction, Mathematical modelling, Time response of dynamical systems, Stability, feedback control, Design of controllers, Frequency domain analysis, design of compensators
7	**Contents for lab**	
8	**Text books/references**	1. G.F. Franklin, J. D. Powell, A. Emami-Naeini, "Feedback Control of Dynamic Systems", Pearson, Upper Saddle River, New Jersey, 5th edition, 2006. 2. K. Ogata, "Modern Control Engineering", Prentice-Hall of India Pvt Ltd., New Delhi, 3rd edition, 2000. 3. B. C. Kuo, "Automatic Control Systems", Prentice-Hall of India Pvt Ltd., New Delhi, 6th, edition, 1991. 4. Nagrath & Gopal, Control Systems

1	**Code of the subject**	CS007
2	**Title of the subject**	System Simulation and Modeling
3	**Prerequisite**	
4	**L-T-P**	3-0-0

5	**Learning Objectives**	Introduce computer simulation technologies and techniques, provide the foundations for the student to understand computer simulation needs, and to implement and test a variety of simulation and data analysis libraries and programs To introduce concepts of modeling layers of society's critical infrastructure networks and to build tools to view and control simulations and their results.
6	**Brief Contents**	Module – 1 Simulation Basics : Handling Stepped and Event-based Time in Simulations, Discrete versus Continuous Modelling, Numerical Techniques, Sources and Propagation of Error Module – 2 Dynamical, Finite State, and Complex Model Simulations: Graph or Network Transitions Based Simulations, Actor Based Simulations, Mesh Based Simulations, Hybrid Simulations Module – 3 Converting to Parallel and Distributed Simulations : Partitioning the Data, Partitioning the Algorithms, Handling Inter-partition Dependencies Module – 4 Probability and Statisics for Simulations and Analysis : Review of terminology, concepts, Useful statistical models, Discrete Distributions ,Continuous Distributions, Poisson Process, Empirical distributions, Introduction to Queues and Random Noise, Random Variates Generation, Sensitivity Analysis, The basics of SpreadSheet-Simulation, Simulation Example: Simulation of queuing systems in a spreadsheet Module 5- Random-Number Generation, Random-Variate Generation : Properties of random numbers, Generation of pseudo-random numbers ,Techniques for generating random numbers ,Tests for Random Numbers, Random- Variate Generation ,Inverse transform technique ,Acceptance-Rejection technique, Special properties Module 6 -Input Modeling: Data Collection, Identifying the distribution with data, Parameter Estimation, Goodness of Fit Tests, Fitting a non-stationary Poisson process ,Selecting input models without data , Multi-variate and Time-Series input models Module 7- Queuing Models: Characteristics of queuing Systems, Queuing notation , Long-run measures of performance of queuing Systems, Steady-state behavior of M/G/1 queue, Networks of queues ,Rough-cut modeling: An illustration. Module – 8 Simulations Results Analysis and Viewing Tools : Display Forms: Tables, Graphs, and Multidimensional Visualization, Terminals, X and MS Windows, and Web Interfaces, Validation of Model Results.
7	**Contents for lab**	
8	**Text books/references**	1. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol: Discrete-Event System Simulation. (Listed topics only from Chapters-1 to 12), 5th Edition, Pearson Education ©2013 2. Averill M. Law: Simulation Modeling and Analysis , 4th Edition, Tata McGraw-Hill, 2007.ISBN : 9780070667334

		3. Lawrence M. Leemis, Stephen K. Park: Discrete – Event Simulation: A First Course,Pearson Education, 2006.ISBN: 978-0131429178

1	**Code of the subject**	CS008
2	**Title of the subject**	IoT Protocols
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives of the subject**	To introduce the terminology, technology and its applications To introduce the concept of M2M (machine to machine) with necessary protocols To introduce the Python Scripting Language which is used in many IoT devices To introduce the Raspberry PI platform, that is widely used in IoT applications To introduce the implementation of web-based services on IoT devices
6	**Brief Contents**	Module 1: Introduction to Signals and systems, Introduction to Internet of Things, Physical Design of IoT – IoT Protocols, IoT communication models, IoT Communication APIs, IoT enabled Technologies – Wireless Sensor Networks, Cloud Computing, Embedded Systems, IoT Levels and Templates, Domain Specific IoTs – Home, City, Environment, Energy, Agriculture and Industry. Module 2: IoT and M2M- Software defined networks, network function virtualization, difference between SDN and NFV for IoT, Basics of IoT System Management with NETCONF, YANG- NETCONF, YANG, SNMP NETOPEER Module 3: IoT Physical Devices and Endpoints- Introduction to Arduino and Raspberry Pi- Installation, Interfaces (serial, SPI, I2C) Controlling Hardware- Connecting LED, Buzzer, Switching High Power devices with transistors, Controlling AC Power devices with Relays, Controlling servo motor, speed control of DC Motor, unipolar and bipolar Stepper motors Module 4: Sensors- Light sensor, temperature sensor with thermistor, voltage sensor, ADC and DAC, Temperature and Humidity Sensor DHT11, Motion Detection Sensors, Wireless Bluetooth Sensors, Level Sensors, USB Sensors, Embedded Sensors, Distance Measurement with ultrasound sensor Module 5: IoT Physical Servers and Cloud Offerings– Introduction to Cloud Storage models and communication APIs Web Server – Web server for IoT, Cloud for IoT, Python web application framework Designing a RESTful web API
7	**Contents for lab**	
8	**List of text books/references**	1. Internet of Things - A Hands-on Approach, Arshdeep Bahga and Vijay Madisetti, Universities Press, 2015, ISBN: 9788173719547 2. Getting Started with Raspberry Pi, Matt Richardson & Shawn Wallace, O'Reilly (SPD), 2014, ISBN: 9789350239759

		3. Raspberry Pi Cookbook, Software and Hardware Problems and solutions, Simon Monk, O'Reilly (SPD), 2016, ISBN 7989352133895

1	**Code of the subject**	CS009
2	**Title of the subject**	Game Programming
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives of the subject**	This course provides an introduction to game engine scripting, event driven and data driven programming, game engine data structures, basic game related graphics and AI concepts.
6	**Brief Contents**	Module 1: Introduction to Game Programming and Unity, The Game Loop, Scene Modeling Module 2: Introduction to Animation, Keyframing, Character Animation and Rigging, Animation Controllers, Game UIs Module 3: Kinematics, Particle Effects, Physics-based Animation, Numerical Integration, Rigid Body Simulation, Collisions, Sound, Procedural Content Generation Module 4: Game AI: Planning, Pathfinding, Decision Making Module 5: Game Networking, Game Business and Ethics
7	**Contents for lab**	
8	**List of text books/references**	1. Mike Mc Shaffrfy and David Graham, “Game Coding Complete”, Fourth Edition, Cengage Learning, PTR, 2012. 2. Jason Gregory, “Game Engine Architecture”, CRC Press / A K Peters, 2009. 3. David H. Eberly, “3D Game Engine Design, Second Edition: A Practical Approach to Real-Time Computer Graphics” 2nd Editions, Morgan Kaufmann, 2006. 4. Ernest Adams and Andrew Rollings, “Fundamentals of Game Design”, 2nd Edition Prentice Hall / New Riders, 2009. 5. Eric Lengyel, “Mathematics for 3D Game Programming and Computer Graphics”, 3rd Edition, Course Technology PTR, 2011. 6. Jesse Schell, The Art of Game Design: A book of lenses, 1st Edition, CRC Press, 2008.

1	**Code of the subject**	CS010
2	**Title of the subject**	Formal Languages and Automata
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives of the subject**	To discuss key notions of computation, such as algorithm, computability, decidability, reducibility, and complexity, through problem solving. To explain the models of computation, including formal languages, grammars and automata, and their connections. state and explain the Church-Turing thesis and its significance. To analyze and design finite automata, pushdown automata, Turing machines, formal languages, and grammars.

		To solve computational problems regarding their computability and complexity and prove the basic results of the theory of computation.
6	**Brief Contents**	Module I:Automata and Languages - finite automata and regular expressions, pushdown automata and context-free grammars, pumping lemmas and closure proprties of regular and context-free languages, non-context-free languages Module II:Computability theory - the Church-Turing thesis, Hilbert's problem, decidability, halting problem, reducibility Module III:Complexity theory - time and space complexity, Classes P, NP, NP-complete, PSPACE, and PSPACE-complete Module IV:Intractability - hierarchy theorem, Relativization, Circuit complexity Module V: Computable Functions- Primitive Recursive Functions, PRF and Bounded Operations, Unbounded. Minimalization and ų-Recursive Functions, Godel Numbering
7	**Contents for lab**	
8	**List of text books/references**	1. M. Sipser, Introduction to the Theory of Computation, Thomson, 2004. 2. H. R. Lewis and C. H. Papadimitriou, Elements of the Theory of Computation, PHI, 1981. 3. J. L. Balcazar, J. Diaz and J. Gabarro, Structural Complexity, Vols 1 & 2, EATCS Monographs, Springer-Verlag, 1987. 4. John Martin. (2010). Introduction to languages and the theory of computation, (4th ed.). New York: McGraw-Hill Science/Engineering/Math. 5. Tourlakis, George J. (2012). Theory of computation. Hoboken: Wiley.

1	**Code of the subject**	CS011
2	**Title of the subject**	Advanced Network Technologies
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To understand the interconnection for high performance computing, protocols and techniques used for enhancing data delivery ratio, ensuring QoS. Wireless sensor networks and protocols to support cyber physical system interaction and components of IoT.
6	**Brief Contents**	Module 1: Gigabit Networking High Performance Computing and Communications Program (HPCC) basics, Broadband networks, Gigabit testbeds worldwide, Network switching technologies: architecture and performance parameters, Gigabit network design preliminaries. Module 2: Wireless Sensor Networks Sensor network architecture, Design principles, Optimization goals and figures of merit, Communication protocols, Link layer protocols, Localization and positioning, Topology control, Routing protocols, Advanced application support. Module 3: Content Delivery Networks

		Early Days of Content Delivery over the Internet World Wide Web—Where It Came From and What It Is Evolution of Content Networking Diversity of Interests in Content Networking; Content Transport: Protocol Architecture and Design Paradigms of the Internet, Hypertext Transport Protocol—HTTP, Multicast Transport; Caching Techniques for Web Content; Caching Techniques for Streaming Media.
7	**Contents for lab**	
8	**List of text books/references**	1. Gigabit Networking‖ (Addison-Wesley Professional Computing Series), Craig Partridge, Addison Wesley, 1994. 2. Protocol and Architectures for Wireless Sensor Networks‖, Holger Karl, Andreas Willig, Wiley, 2005. 3. Content Networking Architecture, Protocols, and Practice‖, M. Hofmann, L. R. Beaumont, .Morgan Kaufmann, 2005.

1	**Code of the subject**	CS012
2	**Title of the subject**	Empirical Techniques in Software Engineering
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	1. Design empirical studies for different purposes (e.g., evaluating a tool, understanding a phenomenon); choose appropriate methods and defend the choice. 2. Collect and analyze qualitative and quantitative data 3. Mine data from online repositories. 4. Run statistical tests and interpret results. 5. Draw conclusions from empirical data.
6	**Brief Contents**	What Is Empirical Software Engineering? Overview of Empirical Studies, Types of Empirical Studies, Empirical Study Process, Basic Elements of Empirical Research Software Metrics: Measurement Basics, OO metrics, dynamic metrics, System Evolution and Evolutionary Metrics, validation of software metrics. Experimental design: Overview of Experimental Design, Research Questions, Research Variables, Hypothesis Formulation, Data Collection, selection of Data analysis methods. Mining Data from Software Repositories: Configuration Management Systems, Importance of Mining Software Repositories, version control system, bug tracking systems, static source code analysis, software historical analysis. Data Analysis and Statistical Testing, Model Development and Interpretation, Validity Threats, Categories of Threats to Validity.
7	**Contents for lab**	
8	**List of text books/references**	1. Empirical Research in Software Engineering Concepts, Analysis, and Applications By Ruchika Malhotra. 2. Clases Wohlin, Per Runeson, Martin Host, Magnus C. Ohlsson, Bjorn Regnell, Anders Wesslen Experimentation in Software Engineering: An Introduction November 1999, Kluwer Academic Pub. 3. Tonella P., Torchiano, M., Du Bois, B., Systa, T. 2007. Empirical studies in reverse engineering: state of the art and

		future trends. In Empirical Software Engineering, Vol. 12(5), Springer, 551-571

1	**Code of the subject**	CS013
2	**Title of the subject**	Digital Water Marking and Steganalysis
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	The objective of the course makes students familiar about Digital watermarking and steganography.
6	**Brief Contents**	Module I-Introduction: Information Hiding, Steganography, and Watermarking, Importance of Digital Watermarking, Steganography Applications and Properties: Applications of Watermarking, Applications of Steganography, Properties of Watermarking Systems, Evaluating Watermarking Systems, Properties of Steganographic and Steganalysis Systems, Evaluating and Testing Steganographic Systems Module II-Models of Watermarking: Communication-Based Models of Watermarking, Geometric Models of Watermarking, Modeling Watermark Detection by Correlation, Basic Message Coding: Mapping Messages into Message Vectors, Error Correction Coding, Detecting Multi-symbol Watermarks Module III- Watermarking with Side Information: Informed Embedding, Watermarking Using Side Information, Dirty-Paper Codes Robust Watermarking: Approaches, Robustness to Volumetric Distortions, Robustness to Temporal and Geometric Distortions Module IV- Watermark Security: Security Requirements, Watermark Security and Cryptography, Some Significant Known Attacks Content Authentication: Exact Authentication, Selective Authentication, Localization, Restoration, Steganography: Notation and Terminology, Information-Theoretic Foundations of Steganography, Practical Steganographic Methods, Minimizing the Embedding Impact Steganalysis: Steganalysis Scenarios, Some Significant Steganalysis Algorithms.
7	**Contents for lab**	
8	**List of text books/references**	1. Digital Watermarking and Steganography, Ingemar J. Cox, Matthew L. Miller, Jeffrey A. Bloom, Jessica Fridrich, Ton Kalker, Morgan Kauffman 2. Digital Watermarking principles, Ingemar J. Cox, Matthew L. Miller, Jeffrey A. Bloom, Morgan Kauffman

1	**Code of the subject**	CS014
2	**Title of the subject**	Deep Learning
3	**Any prerequisite**	
4	**L-T-P**	3-0-0

5	**Learning Objectives**	1. Introduce deep learning algorithms, the problem settings, and their applications to solve real world problems. 2. Provide an understanding of the theoretical basis underlying neural networks and deep learning.
6	**Brief Contents**	Module 1: History of Deep Learning, Deep Learning Success Stories, McCulloch Pitts Neuron, Thresholding Logic, Perceptron, Perceptron Learning Algorithm. Module 2: Multilayer Perceptron (MLPs), Representation Power of MLPs, Sigmoid Neurons, Feedforward Neural Networks, Representation Power of Feedforward Neural Networks Module 3: Gradient Descent (GD), Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam, Eigenvalues and eigenvectors, Eigenvalue Decomposition, Basis. Module 4: Principal Component Analysis and its interpretations, Singular Value Decomposition Module 5: Autoencoders and relation to PCA, Regularization in autoencoders, Denoising autoencoders, Sparse autoencoders, Contractive autoencoders Module 6: Regularization: Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Ensemble methods, Dropout. Module 7: Greedy Layer-wise Pre-training, Better activation functions, Better weight initialization methods, Batch Normalization Module 8: Convolutional Neural Networks, AlexNet, ZF-Net, VGGNet, GoogleNet, ResNet, Visualizing Convolutional Neural Networks, Guided Backpropagation, Deep Dream, Deep Art, Fooling Convolutional Neural Networks Module 9: Recurrent Neural Networks, Backpropagation through time (BPTT), Vanishing and Exploding Gradients, Truncated BPTT, GRU, LSTMs Module 10: Encoder Decoder Models, Attention Mechanism, Attention over images.
7	**Contents for lab**	Exploration and implementation of deep-learning models using Tensor Flow, PyTorch and Caffe.
8	**List of text books/references**	1. Ian Goodfelllow, Yoshua Benjio, Aaron Courville, “Deep Learning”, The MIT Press, 2016. 2. Richard O. Duda, Peter E. Hart, David G. Stork, “Pattern Classification”, John Wiley & Sons Inc. 3. Research Papers.

1	**Code of the subject**	CS015
2	**Title of the subject**	Blockchain Technology
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	• Get an overview of blockchain technology, its history, benefits, drawbacks, and future. • Examine the nascent blockchain technology and make an initial pass at identifying some of its major vulnerabilities.

		• Design, build, and deploy distributed applications • Shall equip students with the skills necessary to create e-governance applications for the public good.
6	**Brief Contents**	Module I: Introduction: Overview of Blockchain, Public Ledgers, Bitcoin, Smart Contracts, Block in a Block chain, Transactions, Distributed Consensus, Types of consensus algorithms, Types of Block chain -Public vs Private Block chain, Understanding Crypto currency, A basic crypto currency Module II: Overview of Security aspects of Block chain. Basic Crypto Primitives: Cryptographic Hash Function, Properties of a hash function, Hash pointer and Merkle tree, Symmetric key cryptography, Asymmetric key cryptography, Public Key cryptography, Digital Signature. Module III: Byzantine General problem and Fault Tolerance, Mining Mechanism, Energy usage, Distributed Consensus, Merkle Tree, Transactions and Fee, Anonymity, Reward, Bitcoin Transaction structure, Double Spending Problem, Privacy in blockchains. Module IV: Introduction to Consensus Problem, Distributed Consensus, Nakamoto consensus, Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS), Leased Proof of Stake (LPoS), Proof of Elapsed Time (PEoT), Tangle, Proof of Burn (PoB), Difficulty Level, Energy utilization and alternate, Consensus in Etherium. Module V: Application of DLT in e-governance, Banking and Finance, Virtual Machine- Swarm and IPFS- Installing IPFS, IPFS file uploader, Understanding blockchain for Enterprises – Project (Eg. Enterprise application of blockchain, Food security, Blockchain enabled Trade, finance network, Supply chain, and Identity on blockchain.)
7	**Contents for lab**	
8	**List of text books/references**	1. Michael E. Whitman and Herbert J. Mattord: Principles of Information Security, 2nd Edition, Cengage Learning, 2005. (Chapters 5, 6, 7, 8; Exclude the topics not mentioned in the syllabus). 2. Behrouz A. Forouzan and Debdeep Mukhopadhyay: Cryptography and Network Security, 2nd Edition Tata McGraw Hill, 2010. (Chapters: 1, 3, 6, 7, 10, 11, 15, 16, 17, 18).

1	**Code of the subject**	CS016
2	**Title of the subject**	Introduction to Robotics
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	The course work will be helpful for the students to understand the basic principles of robotics. They will learn about the components, modelling and basic operations of the robots.

6	**Brief Contents**	SystemsOverview of a Robot, Mechanical Systems, Components, Dynamics and Modeling, Control of Actuators in Robotic Mechanisms, Robotic Sensory Devices. PerformanceDefinition - Accuracy/ Repeatability/ Precision with respect to Position &Path, payload, speed, acceleration, cycle time Challenges/plicationsandusesofMobileandotherrobots: wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitation robots, humanoidrobots Introduction to robot manipulation. Forward and inverse kinematics of robots and some case studies. Manipulator dynamics. Basics of robot control. Taskplanningwith emphasis on computational geometry methods for robot path finding, robot arm reachability, grasp planning etc. Overview of robot vision.
7	**Contents for lab**	
8	**List of text books/references**	1. Richard D. Klafter, Robotic Engineering: An Integrated Approach, Phi 2. R. J. Schilling, Fundamentals of Robotics: Analysis And Control, Prentice-Hall India References: 1. Francis N. Nagy, Andrassiegler, Engineering Foundation of Robotics, Prentice Hall Inc 2. P.A. Janaki Raman, Robotics And Image Processing An Introduction, Tata Mc Graw Hill Publishing Company Ltd. 3. Mikell P. Grooyer, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey, Industrial Robotics, Technology Programming And Applications, Mc Graw Hill International Edition 4. S.R. Deb, Robotics Technology And Flexible Automation, Tata Mc Graw Hill Publishing Company Ltd. 5. Carl D. Crane And Joseph Duffy, Kinematic Analysis Of Robot Manipulation, Cambridge University Press

1	**Code of the subject**	CS017
2	**Title of the subject**	Stochastic Processes and Queuing Theory
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	Many complex systems are modeled using stochastic processes. This course will introduce students to basic stochastic processes tools that can be utilized for performance analysis and stochastic modeling.
6	**Brief Contents**	Review of probability, random variable and expectation Stochastic processes, Discrete-Time Markov Chains, Continuous-Time Markov Chains, Queuing networks
7	**Contents for lab**	

8	**List of text books/references**	1. Introduction to Stochastic Processes‖ , E. Cinlar, Prentice-Hall, 1975. 2. Stochastic Modelling of Queues‖, R. W. Wolf, Prentice-Hall, 1989. 3. Probability & Statistics with Reliability, Queuing and Computer Science Application‖, 2nd ed., Wiley, 2008.

1	**Code of the subject**	CS018
2	**Title of the subject**	Advanced Competitive Programming
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To gain an in-depth knowledge of data structure and algorithms To apply different algorithms in solving real-world problems. To understand the commonly used problem solving techniques
6	**Brief Contents**	Basic Data Structures: Arrays, Strings, Stacks, Queues, Asymptotic analysis (Big-O notation), primality testing, Euclid's GCD Algorithm, Basic Recursion, Greedy Algorithms, Naive string searching, O(n logn) Sorting, Binary Searching, Heaps (priority queue) Advance Data Structure: Disjoint Set Union, Segment Trees, Binary Index Tree (Fenwick tree), Trees traversals, Fundamental of Dynamic Programming, tree dynamic programming GraphAlgorithms:Finding connected components and transitive closures.Shortest-path algorithms (Dijkstra, Bellman-Ford, Floyd-Warshall), Minimum spanning tree (Prim and Kruskal algorithms), Biconnectivity in undirected graphs (bridges, articulation points), Strongly connected components in directed graphs, Topological Sorting. Modular arithmetic including division, inverseAmortized Analysis, Divide and Conquer, Advanced Dynamic Programming problems, Sieve of Eratosthenes Treaps, Persistent Data Structures, HLD, Centroid Decomposition, Computational Geometry, Dynamic Programming Optimizations, Advanced String algorithms (Tries, KMP, Aho-Corasik, Suffix arrays, Suffix trees), Flows (Max-Flow, Min Cost Max Flow)
7	**Contents for lab**	
8	**List of text books/references**	1. Felix Halim and Steven Halim,―Competitive programming 3‖, NUS. 2. Antti and Laaksonen, ―Guide to Competitive Programming: Learning and Improving Algorithms Through Contests‖, 78-3319725468, Springer; 1st ed. 2017 3. NarasimhaKarumanchi, ―Data Structures and Algorithms made easy‖, CareerMonk Publications; Fifth edition, 2016.

1	**Code of the subject**	CS019
2	**Title of the subject**	Network Programming
3	**Any prerequisite**	

4	**L-T-P**	3-0-0
5	**Learning Objectives**	The programming part of the course will be executed through in-class example discussion, homework assignments and term project. Due to the time limit, the lectures will focus mostly on networking concepts and how to achieve them with the selected languages and systems.
6	**Brief Contents**	Module 1: Network and Web basics, Adressing, Naming and DNS Module 2: Socket programming, TCP, UDP programming, Simple client-server programming, Network programming with GUI Module 3: Programming with HTTP for the Internet and WWW, Email, Telnet and FTP Processing XML and JSON data Module 4: Multithreading, multiprocessing, multithreaded servers and clients, Event-driven programming Module 5: Popular Python libraries for your applications
7	**Contents for lab**	
8	**List of text books/references**	1. Abhishek Ratan, Eric Chou, Pradeeban Kathiravelu and Dr. M. O. Faruque Sarker. Python Network Programming. Packt Publishing, 2019. 2. Eric Chou. Mastering Python Networking, 2nd Edition. Packt Publishing, 2018. 3. Josa Manuel Ortega. Mastering Python for Networking and Security. Packt Publishing, 2018. 4. Pradeeban Kathiravelu and Dr. M. O. Faruque Sarker. Python Network Programming Cookbook, 2nd Edition. Packt Publishing, 2017. 5. Dr. M. O. Faruque Sarker and Sam Washington. Learning Python Network Programming, Packt Publishing, 2015. 6. Brandon Rhodes andÂ John Goerzen. Foundations of Python Network ProgrammingÂ 3rd Edition. Apress, 2014.

1	**Code of the subject**	CS020
2	**Title of the subject**	Combinatorial Mathematics
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	The course deals with theory and algorithms for solving integer and combinatorial optimization problems. Topics that are covered include models and algorithms for network flow, matching, assignment, matroids, knapsack problems, relaxations, tree search methods, and cutting plane methods.
6	**Brief Contents**	Fundamental concepts of graphs, trees and distance, shortest paths, disjoint paths, matchings and factors, bipartite matching and vertex cover, connectivity and paths, vertex coloring, edge colouring, edges and cycles, planar graphs, maximum flow, Gomory-Hu trees.

7	**Contents for lab**	1. C. Papadimitriou and K. Steiglitz, Combinatorial optimization: algorithms and complexity, 2nd Edn., Dover, 1998) 2. A. Schrijver, Combinatorial Optimization, Springer-Verlag, 2002. 3. R. J. Wilson, Introduction to Graph Theory, Longman, 1985.
8	**List of text books/references**	1. László Lovász, Combinatorial Problems and Exercises. (AMS Chelsea Publishing); 2nd edition. 2. Noga Alon and Joel H. Spencer, The Probabilistic Method Wiley-Blackwell; 4th revised edition 3. Herbert S. Wilf, Generating Functionology. A K Peters/CRC Press, 3rd edition 4. Stasys Jukna, Extremal Combinatorics: With Applications in Computer Science Springer; 2nd edition

1	**Code of the subject**	CS021
2	**Title of the subject**	Network Design and Optimization
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To study optimization techniques for use in the domain of computer networks. To analyse network infrastructure requirements and to design and implement the infrastructure for business solutions.
6	**Brief Contents**	Introduction to Graphs and Flows -Network Flow Models - Network Flow Algorithms - Shortest Path Problems - Label Setting (Dijkstra) Methods - Label Correcting Methods - Single Origin/Single Destination Methods - Auction Algorithms - Multiple Origin/Multiple Destination Methods Max-Flow and Min-Cost Flow Problem Max-Flow and Min-Cut Problems - Ford-Fulkerson Algorithm - Price-Based Augmenting Path Algorithms - Transformations and Equivalences - Duality Simplex Methods for Min-Cost Flow Main Ideas in Simplex Methods - Basic Simplex Algorithm - Extension to Problems with Upper and Lower Bounds - Implementation Issues Dual Ascent Methods for Min-Cost Flow Dual Ascent -The Primal-Dual (Sequential Shortest Path) Method -The Relaxation Method -Sensitivity Analysis - Implementation Issues Auction Algorithms for Min-Cost Flow The Auction Algorithm for the Assignment Problem - Extensions of the Auction Algorithm -The Preflow-Push Algorithm for Max-Flow -The Relaxation Method - The Auction/Sequential Shortest Path Algorithm - Nonlinear Network Optimization - Convex Separable Network Problems - Network Problems with Integer Constraints
7	**Contents for lab**	

8	**List of text books/references**	1. Network Optimization: Continuous and Discrete Methods‖, Dimitri Bertsekas, 1998. 2. Network Flows: Theory, Algorithms, and Applications‖, James B. Orlin, Ravindra K. Ahuja, and Thomas L. Magnanti, 1993. 3. Network Optimization Problems: Algorithms, Applications And Complexity‖, Panos M. Pardalos, Ding-Zhu Du, 1993. 4. Routing, Flow and Capacity Designing in Communication and Computer Networks‖, M. Pioro and D. Medhi, Morgan Kaufmann, 2004.

1	**Code of the subject**	CS022
2	**Title of the subject**	Software reliability
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	1. Develop reliable software systems. 2. Understand the fault handling and failure forecasting techniques in software systems. 3. Understand different time dependent and time independent software reliability models. 4. Design reliability models for software systems.
6	**Brief Contents**	Basic Ideas of Software Reliability, Hardware reliability vs. Software reliability, Reliability metrics, Failure and Faults – Prevention, Removal, Tolerance, Forecast, Dependability Concept – Failure Behaviour, Characteristics, Maintenance Policy, Reliability and Availability Modeling, Reliability Evaluation Testing methods, Limits, Starvation, Coverage, Filtering, Microscopic Model of Software Risk. Computation of software reliability, Functional and Operational Profile, Operational Profiles – Difficulties, Customer Type, User Type, System Mode, Test Selection - Selecting Operations, Regression Test. Classes of software reliability Models, Time Dependent Software Reliability Models: Time between failure reliability Models, Fault Counting Reliability Models. Time Independent Software Reliability Models: Fault injection model of Software Reliability, Input Domain Reliability Model, Orthogonal defect classification, Software availability Models. Software Reliability Modeling: A general procedure for reliability modeling. Short and Long Term Prediction, Model Accuracy, Analysing Predictive Accuracy – Outcomes, PLR, U and Y Plot, Errors and Inaccuracy, Recalibration – Detecting Bias, Different Techniques, Power of Recalibration, Limitations in Present Techniques, Improvements.
7	**Contents for lab**	
8	**List of text books/references**	1. J.D. Musa, Software Reliability Engineering, McGraw Hill, New York, 2004. 2. H. Pham, Software Reliability, Springer Verlag, New York, 2000. 3. Patric D. T.O Connor, Practical Reliability Engineering, 4th Edition, John Wesley & Sons, 2003.

		4. D. Reled, Software Reliability Methods, Springer Verlag, New York, 2001.

1	**Code of the subject**	CS023
2	**Title of the subject**	Computer Vision
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	Computer Vision focuses on development of algorithms and techniques to analyze and interpret the visible world around us. This requires understanding of the fundamental concepts related to multi-dimensional signal processing, feature extraction, pattern analysis visual geometric modeling, stochastic optimization etc. Applications range from Biometrics, Medical diagnosis, document processing, mining of visual content, to surveillance, advanced rendering.
6	**Brief Contents**	1. Fundamentals of Computer Vision, Affine and Projective Transformation 2. Convolution and Filtering, Image Enhancement, Histogram Processing, 3. Image Segmentation, Region Growing, Edge Based approaches to segmentation, Graph-Cut, Texture Segmentation 4. Object detection, Filters, edge detection techniques, Caney, Sobel, Prewitt 5. K-Means, K-Medoids Clustering, Optical Flow, Spatio-Temporal Analysis, Dynamic Stereo; Motion parameter estimation. 6. Light at Surfaces; Phong Model; Reflectance Map; Albedo estimation
7	**Contents for lab**	
8	**List of text books/references**	1.Digital Image Processing, 3rd Edition Rafael C. Gonzalez, University of Tennessee, Richard E. Woods, Med Data Interactive 2.Computer Vision: A Modern Approach; D. A. Forsyth and J. Ponce; Pearson Education; 2003. 3. Computer Vision: Algorithms and Applications‖ by Richard Szeliski; Springer-Verlag London Limited 2011.

1	**Code of the subject**	CS024
2	**Title of the subject**	Recommender Systems
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	1. To develop state-of-the-art recommender systems that automate a variety of choice-making strategies with the goal of providing affordable, personal, and high-quality recommendations.

		2. Discuss how recommender systems and user models are deployed in e-commerce sites and social networks.
6	**Brief Contents**	Introduction: Recommender system functions, Linear Algebra notation: Matrix addition, Multiplication, transposition, and inverses; covariance matrices, Understanding ratings, Applications of recommendation systems, Issues with recommender system. Collaborative Filtering: User-based nearest neighbour recommendation, Item-based nearest neighbour recommendation, Model based and pre-processing based approaches, Attacks on collaborative recommender systems. Content-based recommendation: High level architecture of content-based systems, Advantages and drawbacks of content-based filtering, Item profiles, discovering features of documents, obtaining item features from tags, Representing item profiles, Methods for learning user profiles, Similarity based retrieval, Classification algorithms. Knowledge based recommendation: Knowledge representation and reasoning, Constraint based recommenders, Case based recommenders. Hybrid approaches: Opportunities for hybridization, Monolithic hybridization design: Feature combination, Feature augmentation, Parallelized hybridization design: Weighted, Switching, Mixed, Pipelined hybridization design: Cascade Meta-level, Limitations of hybridization strategies. Evaluating Recommender System: Introduction, General properties of evaluation research, Evaluation designs, Evaluation on historical datasets, Error metrics, Decision-Support metrics, User-Centred metrics. Recommender Systems and communities: Communities, collaboration and recommender systems in personalized web search, Social tagging recommender systems, Trust and recommendations, Group recommender systems.
7	**Contents for lab**	Implementation of algorithms and techniques using relevant tools or high-level language.
8	**List of text books/references**	1. Dietmar Jannach, Markus Zanker, Alexander Felfernig, Gerhard Friedrich, “Recommender Systems: An Introduction”, Cambridge University Press (2011). 2. Francesco Ricci, Lior Rokach, Bracha Shapira, Paul B. Kantor, “Recommender Systems Handbook”, Springer (2011). 3. Nikos Manouselis, Hendrik Drachsler, Katrien Verbert, Erik Duval, “Recommender Systems for Learning”, Springer.

1	**Code of the subject**	CS025
2	**Title of the subject**	Modern Cryptography
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To make the students understand the process of deciphering coded messages without being told the key. To study of codes and the art of writing and solving them. To give motivation towards recent research development in the field of cryptography, cryptanalysis, and steganography.

		Overall this course explores modern cryptographic (code making) and cryptanalytic (code breaking) techniques in detail.
6	**Brief Contents**	Number Theory Basics Modular arithmetic Fields, Binary Fields Primes, GCD and Chinese reminder theorems Extended Euclidean Algorithm and application Fermat‘s Little Theorem and application Euler Phi function, Block Ciphers in Mathematical way, DES Historical Ciphers (at least 7) Public Key Cryptography, RSA, Two fish.
7	**Contents for lab**	
8	**List of text books/references**	1. "Cryptography: Theory and Practice", Third Edition, by Douglas R. Stinson, CRC Press, Taylor and Francis Group. 2. "Handbook of Applied Cryptography", Fifth Printing, by Alfred J. Menezes, Paul C. van Oorschot, and Scott A. Vanstone, CRC Press. 3. "Cryptography and Network Security: Principles and Practices", Sixth Edition, by William Stallings. 4. The Code Book- The secret history of Codes & Code-breaking‖ by Simon Singh.

1	**Code of the subject**	CS026
2	**Title of the subject**	Robot Motion Planning
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To study algorithms that reason about the movement of physical or virtual entities, To generate sequences of motions for many kinds of robots, robot teams, animated characters, and even molecules.
6	**Brief Contents**	Module 1: An overview of robot motion planning problems. Module 2: Review of basic kinematics of rigid body motion. The configuration space of a rigid body.The classical motion planning paradigms: – the roadmap, the potential field method, – the cellular decomposition and approximate cellular decomposition approaches Module 3: Graph search and discrete planning algorithms. Sensor-Based Motion Planning Algorithms- the “Bug” algorithms - the TangentBug algorithm - the incremental Voronoi Graph - the D∗ algorithm Module 4: Potential field based methods, wave front planners. Non-holonomic systems and planning with kinematic constraints. Module 5: Motion planning for Multi robotic systems, motion planning in 3D
7	**Contents for lab**	
8	**List of text books/references**	1. Planning Algorithms by Steve LaValle (Cambridge Univ. Press, New York, 2006). 2. Principles of Robot Motion: Theory, Algorithms, and Implementations (by Howie Choset, Kevin Lynch, Seth

		Hutchinson, George Kantor, Wolfram Burgard, Ly-dia Kavraki, and Sebastian Thrun). 3. Probabilistic Robotics (by Sebastian Thrun, Wolfram Burgard, and Dieter Fox Lynch). MIT Press, 2005. 4. Robot Motion Planning by J.C. Latombe.

1	**Code of the subject**	CS027
2	**Title of the subject**	Nature Inspired Computing
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	It introduces a new paradigm of computing and solving problems. It has great applications in Artificial Intelligence, Data Mining, Machine Learning, and real-world design and optimization problems.
6	**Brief Contents**	Introduction: Introduction: Nature-inspired Computing, Evolutionary Computation, Swarm Intelligence, Artificial Neural Networks, Fuzzy Systems; Brief History. Evolutionary and Swarm Computing: Introduction to Evolutionary Computation: Representation, Initial Population, Fitness Function, Selection, Reproduction Operators, Stopping Conditions, Evolutionary versus Classical Computation; Genetic Algorithm: Canonical Genetic Algorithm, Crossover, Mutation, Control Parameters, Genetic Algorithm Variants, Applications; Differential Evolution: Basic Differential Evolution, Variants of Basic Differential Evolution, Differential Evolution for Discrete-valued Problems; Particle Swarm Optimization: Basic Particle Swarm Optimization, Social Network Structures, Basic Variants, Basic PSO Parameters, Applications; Artificial Bee Colony Algorithm: Basic ABC, Basic Variants, Basic ABC Parameters, Applications. Artificial Neural network: Introduction: Fundamental Concepts, Evolution, Basic Models, Terminology, McCulloh-Pitts Neuron, Linear Separability, Hebb Network; Supervised Learning Network: Perceptron Networks, Adaptive Linear Neuron, Multiple Adaptive Linear Neuron, Back-Propagation Network, Radial Basis Function Network; Associative Memory Network: Training Algorithms for Pattern Association, Associative Memory Network, Heteroassociative Memory Network, Bidirectional Associative Memory, Hopfield Network, Iterative Autoassociative Memory Network, Temporal Associative Memory Network; Unsupervised Learning Networks: Fixed Weight Competitive Nets, Kohonen Self-Organizing Feature Map, Linear Vector Quantization, Counter Propagation Network, Adaptive Resonance Theory Network. Fuzzy Logic and Fuzzy Sets: Introduction to Classical Sets and Fuzzy Sets: Classical Sets, Fuzzy Sets; Classical Relations and Fuzzy Relations: Classical Relation, Fuzzy Relations, Tolerance and Equivalence Relations, Noninteractive Fuzzy Sets; Membership Functions; Defuzzification; Fuzzy

		Arithmetic and Fuzzy Measures; Fuzzy Rule Base and Approximate Reasoning; Fuzzy Decision Making.
7	**Contents for lab**	
8	**List of text books/references**	1. Principles of Soft Computing, S N Sivanandam and S N Deepa, Wiley 2. Computational Intelligence: An Introduction, Andries P. Engelbrecht, John Wiley & Sons. 3. Neural Networks, Fuzzy Logic, and Genetic Algorithms: Synthesis and Applications, S. Rajasekaran and G. A. Vijayalakshmi Pai, PHI.

1	**Code of the subject**	CS028
2	**Title of the subject**	Game Theory and Applications
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	1. Understanding the basic game theory concepts, including utility, strategies, and Nash equilibrium. 2. Knowledge of advanced game theory concepts, such as repeated games, signalling games, and mechanism design. 3. Understanding the limitations of game theory and its relationship to other decision-making frameworks. 4. Developing critical thinking skills and the ability to apply game theory to evaluate and design strategies in different domains. 5. Knowledge of the use of game theory in various fields, such as economics, political science, and computer science.
6	**Brief Contents**	Introduction to Game Theory, Dominant Strategies and Nash Equilibrium, Alternate Strategies: Maximin, Maximax, and Minimax Regret Solvability, N-Player Games, Mixed Strategy Nash Equilibria, Subgame Perfection in Discrete Choice Games, Continuous Games and Imperfect Competition, Infinitely Repeated Games, Tacit Collusion: An application of Infinites Repeated Games, imperfect Information: Simultaneous-play, ayesian Games, Applications of Bayesian Games: Auctions and Voting, Cournot's Duopoly with Imperfect Information 3.Radio Spectrum, With Arbitrary Distribution of Valuations, Extensive Form Game with Perfect Information, Stackelberg Model of Duopoly, Buying Votes, Committee DecisionMaking, Repeated games, The Prisoner's Dilemma, General Result, Supermodular Game and Potential Game, Supermodular Game and Potential Game, Wireless Networks: Resource Allocations, Admission Control, Routing in Sensor and AdHoc Networks, Modeling Network Traffic and Strategic Network Formation, Rubinstein Bargaining Model with Alternating Offers, Nash Bargaining Solution, Relation of Axiomatic and Strategic Model, Auction and Mechanism Design with Applications, Revenue Equivalence, Risk Averse Bidders, Asymmetries among Bidders, Mechanism, Optimal Mechanism

7	**List of text books/references**	1. Nisan Roughgarden, Tardos, Vazirani (eds), Algorithmic Game Theory, Cambridge University, 2007 2. Maschler, Michael, Shmuel Zamir, and Eilon Solan. Game theory. Cambridge University Press, 2020. 3. Narahari, Yadati. Game theory and mechanism design. Vol. 4. World Scientific, 2014.

1	**Code of the subject**	CS029
2	**Title of the subject**	Human - Computer Interaction
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	The topics covered in the course includes the engineering life cycles for design of interactive systems, computational design framework (as part of the life cycle), components of the framework including the computational models of users and systems, and evaluation of such systems (with or without users).
6	**Brief Contents**	Introduction to user-centric design – case studies, historical evolution, issues and challenges and current trend, Engineering user-centric systems – relation with software engineering, iterative life-cycle, prototyping, guidelines, case studies, User-centric computing – framework, introduction to models, model taxonomy, Computational user models (classical) – GOMS, KLM, Fitts' law, Hick-Hymans law Computational user models (contemporary) 2D and 3D pointing, constrained navigation, mobile typing, touch interaction, Formal models – case study with matrix algebra, specification and verification of properties, formal dialog modeling, Empirical research – research question formulation, experiment design, data analysis, statistical significance test, User-centric design evaluation – overview of evaluation techniques, expert evaluation, user evaluation, model-based evaluation with case studies
7	**Contents for lab**	1. Bhattacharya, S. (July, 2019). Human-Computer Interaction: User-Centric Computing for Design, McGraw-Hill India, Print Edition
8	**List of text books/references**	1. A. Dix, J. Finlay, G. D. Abowd and R. Beale, Human Computer Interaction, 3rd edition, Pearson Education, 2005. References: 1. J. Preece, Y. Rogers, H. Sharp, D. Baniyon, S. Holland and T. Carey, Human Computer Interaction, Addison-Wesley, 1994. 2. C. Stephanidis (ed.), User Interface for All: Concepts, Methods and Tools. Lawrence Erlbaum Associates, 2001. 3. J. M. Caroll (ed.), HCI Models, Theories and Frameworks: Towards a Multidisciplinary Science (Interactive Technologies), Morgan Kauffman, 2003. 4. W. O Galitz, The Essential Guide to User Interface Design, John Wiley & Sons, Inc, 2002 (Indian Edition). 5. B. Shneiderman, Designing the User Interface, Addison Wesley, 2000 (Indian Reprint).

1	**Code of the subject**	CS030
2	**Title of the subject**	Randomized Algorithms
3	**Any prerequisite**	
4	**L-T-P**	3-0-0
5	**Learning Objectives**	To use discrete probability theory to describe and model randomized processes and algorithms, to use discrete probability to analyze the performance of deterministic and randomized algorithms, to design randomized algortihms that solve computational problems of moderate difficulty, to know several standard tail inequalities (Markov inequality, Chebyshev inequality, Chernoff bound) and be able to apply them to analyze perfomance of randomized algorithms.
6	**Brief Contents**	Random numbers: Properties of a random sequence. Generating uniform random numbers: the linear congruential method and others. Statistical tests for random numbers: Chi-square test, Kolmogorov-Smirnov test, empirical / theoretical / spectral tests. Non-uniform random sequences. Tools and techniques of randomized algorithmics: game theoretic techniques, moments and deviations, tail inequalities, the probabilistic method: Lovasz Local Lemma, Markov chains and random walks, algebraic techniques. Applications: Data structures, hashing, linear programming, computational geometry problems, graph problems, approximate algorithms, parallel and distributed algorithms, cryptography, online algorithms. Derandomization techniques.
7	**Contents for lab**	1. R. Motwani and P. Raghavan, Randomized Algorithms, Cambridge University Press, 1995. 2. D. E. Knuth, The Art of Computer Programming, 3rd Ed, Vol 2, Seminumerical Algorithms, Addison-Wesley, 1998. 3. W. Feller, An Introduction to Probability Theo
8	**List of text books/references**	1. Randomized Algorithms, by Motwani and Raghavan, Cambridge University Press, 1995. 2. Probability and Computing: Randomized Algorithms and Probabilistic Analysis, by Mitzenmacher and Upfal, Cambridge University Press, 2nd edition, 2017. Reference Books: 1. Computational Geometry: Algorithms and Applications, by Mark de Berg, Otfried Cheong, Marc van Kreveld, and Mark Overmars, 3rd edition, Springer-Verlag, 2008. 2. Algorithmic and Analysis Techniques in Property Testing, by Dana Ron. Found. Trends Theor. Comput. Sci. 5, 2 (February 2010), 73-205. 3. Mining of Massive Datasets, by Leskovec, Rajaraman, and Ullman