Mathematics and computing

Semester III						
Sr No	**Course code**	**Course name**	**L**	**T**	**P**	**C**
1	CS 205	Design and Analysis of Algorithms	3	0	0	6
2	CS 203	Discrete Structures	3	0	0	6
3	EE 221	Introduction to Probability	3	0	0	3
4	EE 227	Data Analysis	3	0	0	3
5	HS 201	Economics	3	0	0	6
6	CS 213	Software Systems Laboratory	1	3	0	8
7	CS 403	Graph Theory and Combinatorics	3	0	0	6
Total credits						38

Mathematics and computing

1	**Title of the course (L-T-P-C)**	**Design and Analysis of Algorithms (3-0-0-6)**
2	**Pre-requisite courses(s)**	**Computer Programming and Utilization, Discrete Structures, Data Structures and Algorithms, Data Structures and Algorithms Laboratory**
3	**Course content**	Syllabus is divided roughly 8 modules; each module roughly takes two weeks. **Module 1:** Introduction Examples and motivation. Asymptotic complexity: informal concepts, formal notation, examples **Module 2:** Searching in list: binary search, Sorting: insertion sort, selection sort, merge sort, quicksort, stability and other issues. **Module 3:** Divide and conquer: binary search, recurrence relations. nearest pair of points, merge sort, integer multiplication, matrix multiplication. **Module 4:** Graphs: Motivation, BFS, DFS, DFS numbering and applications, directed acyclic graphs, directed acyclic graphs, shortest paths: unweighted and weighted, Single source shortest paths: Dijkstra, Minimum cost spanning trees: Prim's algorithm, Kruskal's Algorithm **Module 5:** Union-Find data structure, Priority queues, heaps. Heap sort. Dijstra/Prims revisited using heaps, Search Trees: Introduction Traversals, insertions, deletions Balancing. **Module 6:** Greedy algorithms: Greedy: Interval scheduling, Proof strategies, Huffman coding. **Module 7:** Dynamic Programming: weighted interval scheduling, memoization, edit distance, longest ascending subsequence. matrix multiplication, shortest paths: Bellman Ford, shortest paths: Floyd Warshall **Module 8:** Intractability: NP completeness, reductions, examples, Misc topics.
4	**Texts/References**	**1.** Algorithms, by Sanjoy Dasgupta, Christos Papadimitriou and Umesh Vazirani, McGraw Hill Education, 2006. **2.** Introduction to Algorithms, 3rd edition, by Cormen, Leiserson, Rivest and Stein, PHI Learning Pvt. Ltd., 2010. **3.** Algorithm Design, 1st edition, by Kleniberg and Tardos, Pearson, 2014.

1	**Title of the course (L-T-P-C)**	**Discrete Structures** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	There are four modules in the course: 1. **Proofs and structures** Introduction, propositions, predicates, examples oftheorems and proofs, types of proof techniques, Axioms, Mathematical Induction, Well-ordering principle, Strong Induction, Sets, Russell's paradox, infinite sets, functions, Countable and uncountable sets, Cantor's diagonalization technique, Relations, Equivalence relations, partitions of a set. 2. **Counting and Combinatorics** Permutations, combinations, binomial theorem, pigeonhole principle, principles of inclusion and exclusion, double counting. Recurrence relations, solvingrecurrence relations. 3. **Elements of graph theory** Graph models, representations, connectivity, Euler andHamiltonian paths, planar graphs, Trees and tree traversals. 4. **Introduction to abstract algebra and numbertheory** Semigroups, monoids, groups, homomorphisms, normal subgroups, congruence relations. Ceiling, floor functions, divisibility. Modular arithmetic, primenumbers, primality theorems.
4	**Texts/References**	1. Discrete Mathematics and its applications with Combinatorics and graph theory, 7th edition, by Kenneth H Rosen. Special Indian Edition published byMcGraw-Hill Education, 2017. 2. Introduction to Graph Theory, 2nd Edition, by Douglas B West. Eastern Economy Edition published by PHI Learning Pvt. Ltd, 2002. 3. Discrete Mathematics, 2nd Edition, by Norman L Biggs. Indian Edition published by Oxford UniversityPress, 2003.

1	**Title of the course (L-T-P-C)**	**Introduction to Probability (3-0-0-3)**
2	**Pre-requisite courses(s)**	**Basic calculus**
3	**Course content**	**Introduction**: Motivation for studying the course, revision of basic math required, connection between probability and length on subsets of the real line, probability-formal definition, events and σ-algebra, independence of events, and conditional probability, sequence of events, and Borel-Cantell Lemma. **Random Variables**: Definition of random variables, and types of random variables, CDF, PDF and its properties, random vectors and independence, brief introduction to transformation of random variables, introduction to Gaussian random vectors. **Mathematical Expectations**: Importance of averages through examples, definition of expectation, moments and conditional expectation, use of MGF, PGF and characteristic functions, variance and k-th moment, MMSE estimation. **Inequalities and Notions of convergence**: Markov, Chebychev, Chernoff and Mcdiarmid inequalities, convergence in probability, mean, and almost sure, law of large numbers and central limit theorem. **A short introduction to Random Process:** Example and formal definition, stationarity, autocorrelation, and cross correlation function, definition of ergodicity.
4	**Texts/References**	1. **Robert B. Ash**, ``Basic Probability Theory," Reprint of the John Wiley & Sons, Inc., New York, 1970 edition. 2. **Sheldon Ross**, ``A first course in probability," Pearson Education India, 2002. 3. **Bruce Hayek**, ``An Exploration of Random Processes for Engineers," Lecture notes, 2012. 4. D.P.Bertsekas and J.Tsitisklis, "Introduction to Probability" MIT Lecture notes, 2000 5. (*link*:https://www.vfu.bg/en/e-Learning/Math-Bertsekas_Tsitsiklis_Introduction_to_probability.pdf)

1	**Title of the course (L-T-P-C)**	**Data Analysis** **(3-0-0-3)**
2	**Pre-requisite courses(s)**	**Introduction to Probability**
3	**Course content**	The role of statistics. Graphical and numerical methods for describing and summarizing data. Sampling variability and sampling distributions, Estimation using a single sample, Hypothesis testing using a single sample, Comparing two populations or treatments, Simple linear regression and correlation, and Case studies.
4	**Texts/References**	**1.** Sheldon M. Ross, "Introduction to Probability and Statistics for Engineers and Scientists," Elsevier, New Delhi, 3rd edition (Indian), 1987. **2.** Papoulis and Pillai, "Probability, Random Variables and Stochastic processes," 4th Edition, Tata McGraw Hill, 1991. **3.** William Feller, "An Introduction to Probability Theory and Its Applications," Vol. 1, 3rd edition, John Wiley International, 1968.

1	**Title of the course (L-T-P-C)**	**Economics (3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Basic economic problems. resource constraints and Welfare maximizations. Nature of Economics: Positive and normative economics; Micro and macroeconomics, Basic concepts in economics. The role of the State in economic activity; market and government failures; New Economic Policy in India. Theory of utility and consumer choice. Theories of demand, supply and market equilibrium. Theories of firm, production, and costs. Market structures. Perfect and imperfect competition, oligopoly, monopoly. An overview of macroeconomics, measurement, and determination of national income. Consumption, savings, and investments. Commercial and central banking. Relationship between money, output and prices. Inflation - causes, consequences and remedies. International trade, foreign exchange and balance payments, stabilization policies: Monetary, Fiscal and Exchange rate policies.
4	**Texts/References**	**1.** P. A. Samuelson & W. D. Nordhaus, Economics, McGraw Hill, NY, 1995. **2.** A. Koutsoyiannis, Modern Microeconomics, Macmillan, 1975. R. Pindyck and D.L.Rubinfeld, Microeconomics, Macmillan publishing company, NY, 1989. **3.** R. J. Gordon, Macroeconomics 4th edition, Little Brown and Co., Boston, 1987. **4.** William F. Shughart II, The Organization of Industry, Richard D. Irwin, Illinois, 1990. **5.** R.S. Pindyck and D.L. Rubinfeld. Microeconomics The (7Edition), Pearson Prentice Hall, New Jersey, 2009. **6.** R. Dornbusch, S. Fischer, and R. Startz. Macroeconomics (9^{th} edition), McGraw-Hill Inc. New York, 2004.

1	**Title of the course (L-T-P-C)**	**Software Systems Laboratory (1-3-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	1. Vim/emacs HTML, CSS 2. Report and presentation software: latex, beamer,drawingsoftware 3. e.g. inkscape, xfig, open office) 4. IDE (e.g.eclipse, netbeans), code reading,debugging Basic Java collections, interfaces. 5. Java threads Java GUI Introduction todocumentation: 6. e.g. doxygen/javadocs 7. Version management: SVN/Git 8. Unix basics: shell, file system, permissions, processhierarchy, process monitoring, ssh, rsync 9. Unix tools: e.g. awk, sed, grep, find, head, tail, tar,cut, sort 10. Bash scripting: I/O redirection, pipes 11. Python programming 12. Makefile, libraries and linking. 13. Graph plotting software (e.g., gnuplot) 14. Profiling tools (e.g., gprof, prof) Optional topics (may be specific to individualstudents302222 projects): intro to sockets, basic SQL for data storage, JDBC/pygresql. A project would be included which touches upon manyof the above topics, helping students see the connection across seemingly disparate topics. The project is also expected to be a significant load: 20-30 hours of work.
4	**Texts/References**	1. Online tutorials for HTML/CSS, Inkscape, OODrawUnix Man Pages for all unix tools, AdvancedBash Scripting Guide from the Linux Documentation Project (www.tldp.org). 2. The Python Tutorial Online Book(http://docs.python.org/3/tutorial/index.html). 3. The Java Tutorials (http://docs.oracle.com/javase/tutorial/). 4. Latex - A document preparation system, 2/e, byLeslie Lamport, Addison-Wesley, 1994.

1	**Title of the course (L-T-P-C)**	**Graph Theory and Combinatorics (3-0-0-6)**
2	**Pre-requisite courses(s)**	**Discrete Structures**
3	**Course content**	Fundamentals of graph theory. Topics include connectivity, planarity, perfect graphs, coloring matchings and extremal problems. Basic concepts in combinatorics. Topics include counting techniques, inclusion-exclusion principles, permutations, combinations and pigeon- hole principle.
4	**Texts/References**	"An Introduction to Quantum Field Theory", Michael Peskin and Daniel Schroeder (Addison Wesley) "Introduction to Quantum Field Theory", A. Zee "Quantum Field Theory", Lewis H. Ryder "Quantum Field Theory and Critical Phenomena", by Jean Zinn-Justin. "Quantum field Theory for the Gifted Amateur", T. Lancaster and Stephen J. Blundell NPTEL lectures in Quantum Field Theory (https://nptel.ac.in/courses/115106065/)