Approved in 44th BoA Meeting (24-11-2021)

Course number : CS513
Course Name : Discrete Mathematics
Credit : 4
Distribution : 3-1-0-4
Intended for : MTech CSE
Prerequisite : none
Mutual Exclusion: CS208 and CS511.

---

1. Preamble:

This course introduces students to formal reasoning and the mathematics of discrete structures which build the mathematical foundation of Computer Science. On completion of the course, students should be able to apply methods of mathematics in the areas of algorithm design, analysis and verification, automata theory and computability, knowledge representation, formal reasoning, information systems, and information security. In particular, the students should be able to

- use logical notation to define fundamental mathematical concepts such as sets, relations, functions and various algebraic structures, reason mathematically using such structures, and evaluate arguments that use such structures.
- model and analyse a computation process and construct elementary proofs based on such structures.

2. Course Modules with quantitative lecture hours:

1. Logic: (8 hours)

Propositional logic syntax and semantics (revision); proof system and deduction; soundness and completeness; principle of resolution; (ordered) binary decision diagrams; first order logic syntax and semantics; structures, models, satisfaction and validity; resolution; unification; proof systems; axiomatization, soundness, completeness and incompleteness theorems; undecidability of validity problem.

2. Infinite and Structured Sets: (12 hours)

Countable and uncountable sets, Cantor's diagonalization. Turing machines, Church-

Turing Thesis. undecidability of the halting problem. consequences to the program verification problem.

Abstract Algebra: Homomorphism, Fundamental Theorem of homomorphisms, posets and lattices, formal contexts, monoids, semigroups, groupoids and groups, subgroups, cosets, Lagrange' theorem, rings, fields.

3. Combinatorics & Graph Theory: (12 hours)

Counting arguments, recurrence relations, generating functions (Ménage problem), formal power series (ring).

Basics of graph theory (revision), planar graphs (Kuratowski's theorem), minor graphs (Wagner's theorem, Robertson-Seymour theorem) matching and covering (Hall's theorem, Tuttle's theorem, Gallai/Milgram's theorem, connectivity and network flows, coloring (Brooks' theorem, Vizing's theorem), intersection and perfect graphs, sparse and dense graphs.

4. Probability Theory: (10 hours)

Recap of basic probability theory: axiomatic definition, discrete and continuous random variables, functions of random variables; joint, marginal, conditional distributions, Expectation and variance, Moment generating function and characteristic functions.

Moments and deviations (Stable marriage problem, the coupon collector's problem), Concentration inequalities (Chernoff and Hoeffding bounds), Markov Chains and random walks (Expanders). Monte Carlo method.

Laboratory/practical/tutorial Modules:

Tutorials on each of the above course modules (14 hours)

3. Text books:

1. K. H. Rosen, "Discrete Mathematics and Its Applications", 8/e, McGraw Hill Edu., 2019.
2. D. S. Dummit and R. M. Foote, "Abstract Algebra", 3/e, Wiley, 2004.
3. M. Mitzenmacher and E. Upfal, "Probability and Computing", 2/e, Cambridge Univ. Press, 2017.

4. References:

1. Dirk van Daalen: Logic & Structure, Springer, 2008.
2. Uwe Schoening: Logic for Computer Scientists, Springer, 2008
3. Michael Huth, Mark Ryan: Logic in Computer Science: Modelling and Reasoning about Systems, Cambridge Univ. Press 2004.

4. B. Ganter, R. Wille: Formal Concept Analysis, Springer, 1996.
5. P. M. Cohn, Universal Algebra, Springer, 1981.
6. W. Wechler, Universal Algebra for Computer Scientists, Springer, 1992.
7. Reinhard Diestel, Graph Theory, 5/e, Springer, 2017.
8. Bela Bollobas, Modern Graph Theory, Springer, 1998.

5. Similarity with the existing courses:
(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.	Course Code	Similarity Content	Approx. % of Content
1.	CS208	A few modules in Logic and Countability	20%
2.	CS511	Topics in probability theory	25%

6. Justification of new course proposal if cumulative similarity content is >30%:
The course is in the core course basket of M.Tech(CSE) for students specializing in systems engineering. It cannot be taken alongside CS511 which is a 2-credit course for students specializing in Intelligent Systems.