Lecture abstracts for the CIMPA School, 2026

Lecture 1: Introduction to Combinatorics and Graph Theory

This lecture introduces participants to combinatorics and graph theory, providing a foundational understanding of these fields and their applications. It covers basic principles of counting, permutations, combinations, and the pigeonhole principle, along with real-world applications in scheduling, network design, and optimization. The fundamentals of graph theory are also explored, including definitions, properties, and key concepts like graph representations, isomorphism, and special graphs such as trees and bipartite graphs. Learning objectives include understanding basic concepts, applying techniques to solve problems, and appreciating the wide range of applications. The lecture features an interactive Q &A session and hands-on exercises to reinforce learning and engagement, laying the groundwork for more advanced topics.

Lecture 2: Enumerative Combinatorics

This advanced course explores the techniques and principles of enumerative combinatorics, focusing on counting the number of ways certain patterns can be formed. It covers fundamental counting techniques, generating functions, recurrence relations, and advanced topics like Pólya's enumeration theorem and partition theory. Participants will master various counting principles, learn to use generating functions, solve recurrence relations, and understand advanced concepts such as asymptotic methods. The course includes interactive problem-solving sessions and case studies to apply the techniques learned, equipping participants with the skills to tackle complex counting problems in various fields.

Lecture 3: Graph Algorithms and Programming

This session provides practical experience in implementing and understanding key graph algorithms using Python. It covers fundamental algorithms in graph theory and their real-world applications. Participants will learn about graph algorithms, Python libraries like NetworkX, shortest path algorithms (Dijkstra's, Bellman-Ford), network flow algorithms (Ford-Fulkerson, Edmonds- Karp), and graph traversal algorithms (DFS, BFS, topological sorting). The session includes hands-on exercises, collaborative projects, and Q&A sessions to reinforce learning and practical application, enhancing programming skills and understanding of algorithm applications in various domains.

Lecture 4: Metric Graph Theory and Applications

Metric Graph Theory explores distance-based graph parameters, such as diameter, radius, and eccentricity, which play crucial roles in network analysis. These properties help identify central nodes, shortest paths, and connectivity structures, making them essential in transportation systems, communication networks, and social sciences. Applications extend to optimization problems, biological modeling, and algorithmic efficiency, demonstrating how graph-theoretic distances shape real-world structures. This lecture bridges mathematical foundations with practical applications, showing how distance metrics enhance understanding and decision-making in complex networks.

Lecture 5: Extremal Graph Theory

This advanced course delves into extremal graph theory, focusing on the maximum or minimum properties of graphs under specific constraints. Key topics include Turán's Theorem, Ramsey Theory, and extremal functions, with discussions on real-world applications in network design, computer science, and combinatorial optimization. Participants will gain a deep understanding of fundamental theorems, develop problem-solving skills, and explore the broad applications of extremal graph theory. The course features interactive problem- solving sessions to reinforce learning and practical application. Overall, it equips participants with the skills to tackle advanced problems in this field.

Lecture 6: Matroid Theory

This introductory course offers a comprehensive overview of matroid theory, a branch of combinatorics that extends the concept of linear independence in vector spaces to more abstract settings. The course covers basic definitions and examples, matroid representations using graphs and matrices, key theorems such as the Matroid Intersection and Union Theorems, and practical applications in optimization, network flows, and greedy algorithms. Participants will gain a solid understanding of core concepts, learn to represent matroids using various mathematical structures, and apply theoretical knowledge to solve practical problems. The course includes interactive problem-solving sessions to reinforce learning and develop practical skills, preparing participants for advanced study and research in matroid theory.

Lecture 7: Topological Graph Theory

This advanced course delves into the intersection of graph theory and topology, focusing on the study of graphs embedded in surfaces and their topological properties. Key topics include graph embeddings on surfaces like the plane, sphere, and torus, topological invariants such as the Euler characteristic and genus, and the role of graph minors in characterizing planar graphs, including Kuratowski's theorem. The course also discusses applications in network design, molecular biology, and geometric graph theory. Participants will gain a solid understanding of embeddings, explore topological invariants, and apply theoretical concepts to solve practical problems. Interactive components include hands-on exercises and collaborative projects to reinforce learning and practical application, equipping participants with the skills to analyze and apply topological graph theory in various contexts.