Random Walk and the Heat Equation (Student Mathematical Library)

Gregory F. Lawler

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The heat equation can be derived by averaging over a very large number of particles. Traditionally, the resulting PDE is studied as a deterministic equation, an approach that has brought many significant results and a deep understanding of the equation and its solutions. By studying the heat equation by considering the individual random particles, however, one gains further intuition into the problem. While this is now standard for many researchers, this approach is generally not presented at the undergraduate level. In this book, Lawler introduces the heat equation and the closely related notion of harmonic functions from a probabilistic perspective. The theme of the first two chapters of the book is the relationship between random walks and the heat equation. The first chapter discusses the discrete case, random walk and the heat equation on the integer lattice; and the second chapter discusses the continuous case, Brownian motion and the usual heat equation. Relationships are shown between the two. For example, solving the heat equation in the discrete setting becomes a problem of diagonalization of symmetric matrices, which becomes a problem in Fourier series in the continuous case. Random walk and Brownian motion are introduced and developed from first principles. The latter two chapters discuss different topics: martingales and fractal dimension, with the chapters tied together by one example, a random Cantor set. The idea of this book is to merge probabilistic and deterministic approaches to heat flow. It is also intended as a bridge from undergraduate analysis to graduate and research perspectives. The book is suitable for advanced undergraduates, particularly those considering graduate work in mathematics or related areas.

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