

# Stochastic Processes

## Chapter 1 Introduction to Probability Theory

0. Reading:

- Ross Chap 1 (main reading)
- Rosenthal Chap 1 (a discussion on why we need measure theory, and the existence of a nonmeasurable set)
- Shreve §1.1 (a deeper discussion on  $\sigma$ -algebra and countable additivity)

1. Formal definition of probability space  $(\Omega, \mathcal{F}, P)$

• **Definition:**

The set of all possible outcomes of an experiment is called the **sample space** and is denoted by  $\Omega$ . An outcome (sample point) is denoted by  $\omega \in \Omega$ .

• **Definition:**

A collection  $\mathcal{F}$  of subsets of  $\Omega$  is called a  **$\sigma$ -field** ( $\sigma$ -algebra, filtration) if it satisfies the following conditions:

- (a)  $\emptyset \in \mathcal{F}$ ;
- (b) if  $A_1, A_2, \dots \in \mathcal{F}$ , then  $\bigcup_{i=1}^{\infty} A_i \in \mathcal{F}$ ;
- (c) if  $A \in \mathcal{F}$ , then  $A^c \in \mathcal{F}$ .

• **Definition:**

A **probability measure**  $P$  on  $(\Omega, \mathcal{F})$  is a function  $P: \mathcal{F} \rightarrow [0, 1]$  satisfying

- (a)  $0 \leq P(A) \leq 1$ ;
- (b)  $P(\Omega) = 1$ ;
- (c) if  $A_1, A_2, \dots$  is a collection of disjoint (mutually exclusive) members of  $\mathcal{F}$ , in that  $A_i \cap A_j = \emptyset$  for all pairs  $i, j$  satisfying  $i \neq j$ , then

$$P\left(\bigcup_{i=1}^{\infty} A_i\right) = \sum_{i=1}^{\infty} P(A_i).$$

• **Discussion:**

- (a) Why not “finitely additive” but “countably additive”?
- (b) What’s wrong with “uncountably additive”?
- (c) What is a “measure”? What is an event? What does “measurable” mean?

# Introduction To Stochastic Processes Lecture Notes

**Joseph Zaremba**



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## **Table of Contents Introduction To Stochastic Processes Lecture Notes**

1. Understanding the eBook Introduction To Stochastic Processes Lecture Notes
  - The Rise of Digital Reading Introduction To Stochastic Processes Lecture Notes
  - Advantages of eBooks Over Traditional Books
2. Identifying Introduction To Stochastic Processes Lecture Notes
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Introduction To Stochastic Processes Lecture Notes
  - User-Friendly Interface
4. Exploring eBook Recommendations from Introduction To Stochastic Processes Lecture Notes
  - Personalized Recommendations
  - Introduction To Stochastic Processes Lecture Notes User Reviews and Ratings
  - Introduction To Stochastic Processes Lecture Notes and Bestseller Lists
5. Accessing Introduction To Stochastic Processes Lecture Notes Free and Paid eBooks

- Introduction To Stochastic Processes Lecture Notes Public Domain eBooks
  - Introduction To Stochastic Processes Lecture Notes eBook Subscription Services
  - Introduction To Stochastic Processes Lecture Notes Budget-Friendly Options
6. Navigating Introduction To Stochastic Processes Lecture Notes eBook Formats
- ePub, PDF, MOBI, and More
  - Introduction To Stochastic Processes Lecture Notes Compatibility with Devices
  - Introduction To Stochastic Processes Lecture Notes Enhanced eBook Features
7. Enhancing Your Reading Experience
- Adjustable Fonts and Text Sizes of Introduction To Stochastic Processes Lecture Notes
  - Highlighting and Note-Taking Introduction To Stochastic Processes Lecture Notes
  - Interactive Elements Introduction To Stochastic Processes Lecture Notes
8. Staying Engaged with Introduction To Stochastic Processes Lecture Notes
- Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Introduction To Stochastic Processes Lecture Notes
9. Balancing eBooks and Physical Books Introduction To Stochastic Processes Lecture Notes
- Benefits of a Digital Library
  - Creating a Diverse Reading Collection Introduction To Stochastic Processes Lecture Notes
10. Overcoming Reading Challenges
- Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Introduction To Stochastic Processes Lecture Notes
- Setting Reading Goals Introduction To Stochastic Processes Lecture Notes
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Introduction To Stochastic Processes Lecture Notes
- Fact-Checking eBook Content of Introduction To Stochastic Processes Lecture Notes
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
- Utilizing eBooks for Skill Development

- Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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