

Contents

Preface xi

1 Introduction to Probability 1

- 1.1 The History of Probability 1
- 1.2 Interpretations of Probability 2
- 1.3 Experiments and Events 5
- 1.4 Set Theory 6
- 1.5 The Definition of Probability 12
- 1.6 Finite Sample Spaces 19
- 1.7 Counting Methods 22
- 1.8 Combinatorial Methods 28
- 1.9 Multinomial Coefficients 35
- 1.10 The Probability of a Union of Events 39
- 1.11 Statistical Swindles 45
- 1.12 Supplementary Exercises 47

2 Conditional Probability 49

- 2.1 The Definition of Conditional Probability 49
- 2.2 Independent Events 56
- 2.3 Bayes' Theorem 66
- * 2.4 Markov Chains 79
- * 2.5 The Gambler's Ruin Problem 89
- 2.6 Supplementary Exercises 93

3 Random Variables and Distributions 97

- 3.1 Random Variables and Discrete Distributions 97
- 3.2 Continuous Distributions 103
- 3.3 The Distribution Function 109
- 3.4 Bivariate Distributions 118
- 3.5 Marginal Distributions 128
- 3.6 Conditional Distributions 136
- 3.7 Multivariate Distributions 146
- 3.8 Functions of a Random Variable 158
- 3.9 Functions of Two or More Random Variables 165
- 3.10 Supplementary Exercises 176

4 Expectation 181

- 4.1 The Expectation of a Random Variable 181
- 4.2 Properties of Expectations 189
- 4.3 Variance 197
- 4.4 Moments 203
- 4.5 The Mean and the Median 209
- 4.6 Covariance and Correlation 214
- 4.7 Conditional Expectation 222
- 4.8 The Sample Mean 229
- * 4.9 Utility 236
- 4.10 Supplementary Exercises 243

5 Special Distributions 247

- 5.1 Introduction 247
- 5.2 The Bernoulli and Binomial Distributions 247
- 5.3 The Hypergeometric Distribution 251
- 5.4 The Poisson Distribution 255
- 5.5 The Negative Binomial Distribution 263
- 5.6 The Normal Distribution 268
- 5.7 The Central Limit Theorem 282
- 5.8 The Correction for Continuity 291
- 5.9 The Gamma Distribution 295
- 5.10 The Beta Distribution 303
- 5.11 The Multinomial Distribution 309
- 5.12 The Bivariate Normal Distribution 313
- 5.13 Supplementary Exercises 320

6 Estimation 323

- 6.1 Statistical Inference 323
- 6.2 Prior and Posterior Distributions 327
- 6.3 Conjugate Prior Distributions 335
- 6.4 Bayes Estimators 346
- 6.5 Maximum Likelihood Estimators 355
- 6.6 Properties of Maximum Likelihood Estimators 364
- * 6.7 Sufficient Statistics 370
- * 6.8 Jointly Sufficient Statistics 377
- * 6.9 Improving an Estimator 383
- 6.10 Supplementary Exercises 389

7 Sampling Distributions of Estimators 391

- 7.1 The Sampling Distribution of a Statistic 391
- 7.2 The Chi-Square Distribution 393
- 7.3 Joint Distribution of the Sample Mean and Sample Variance 399
- 7.4 The t Distribution 404
- 7.5 Confidence Intervals 409
- * 7.6 Bayesian Analysis of Samples from a Normal Distribution 416
- 7.7 Unbiased Estimators 427
- * 7.8 Fisher Information 435
- 7.9 Supplementary Exercises 446

8 Testing Hypotheses 449

- 8.1 Problems of Testing Hypotheses 449
- * 8.2 Testing Simple Hypotheses 463
- * 8.3 Uniformly Most Powerful Tests 470
- * 8.4 Two-Sided Alternatives 479
- 8.5 The t Test 485
- 8.6 Comparing the Means of Two Normal Distributions 498
- 8.7 The F Distribution 506
- * 8.8 Bayes Test Procedures 514
- * 8.9 Foundational Issues 527
- 8.10 Supplementary Exercises 531

9 Categorical Data and Nonparametric Methods

- 9.1 Tests of Goodness-of-Fit 535

9.2	Goodness-of-Fit for Composite Hypotheses	542
9.3	Contingency Tables	550
9.4	Tests of Homogeneity	556
9.5	Simpson's Paradox	562
* 9.6	Kolmogorov-Smirnov Tests	566
* 9.7	Robust Estimation	575
* 9.8	Sign and Rank Tests	587
9.9	Supplementary Exercises	595

10 Linear Statistical Models 599

10.1	The Method of Least Squares	599
10.2	Regression	609
10.3	Statistical Inference in Simple Linear Regression	618
* 10.4	Bayesian Inference in Simple Linear Regression	638
10.5	The General Linear Model and Multiple Regression	645
10.6	Analysis of Variance	665
* 10.7	The Two-Way Layout	673
* 10.8	The Two-Way Layout with Replications	683
10.9	Supplementary Exercises	694

11 Simulation 699

11.1	Why Is Simulation Useful?	699
11.2	Simulating Specific Distributions	713
11.3	Importance Sampling	727
* 11.4	Markov Chain Monte Carlo	735
11.5	The Bootstrap	753
11.6	Supplementary Exercises	765

Tables 769

Answers to Odd-Numbered Exercises 781

References 801

Index 807