

CHAPTER 1 The Role of Statistics in Engineering 1

- 1-1 The Engineering Method and Statistical Thinking 2
- 1-2 Collecting Engineering Data 6
 - 1-2.1 Retrospective Study 7
 - 1-2.2 Observational Study 8
 - 1-2.3 Designed Experiments 9
 - 1-2.4 Random Samples 12
- 1-3 Mechanistic and Empirical Models 15
- 1-4 Observing Processes Over Time 17

CHAPTER 2 Data Summary and Presentation 23

- 2-1 Data Summary and Display 24
- 2-2 Stem-and-Leaf Diagram 29
- 2-3 Histograms 34
- 2-4 Box Plot 39
- 2-5 Time Series Plots 41
- 2-6 Multivariate Data 46

CHAPTER 3 Random Variables and Probability Distributions 57

- 3-1 Introduction 58
- 3-2 Random Variables 60
- 3-3 Probability 62
- 3-4 Continuous Random Variables 66
 - 3-4.1 Probability Density Function 66
 - 3-4.2 Cumulative Distribution Function 68
 - 3-4.3 Mean and Variance 70
- 3-5 Important Continuous Distributions 74
 - 3-5.1 Normal Distribution 74
 - 3-5.2 Lognormal Distribution 84
 - 3-5.3 Gamma Distribution 86
 - 3-5.4 Weibull Distribution 86
 - 3-5.5 Beta Distribution 88
- 3-6 Probability Plots 92
 - 3-6.1 Normal Probability Plots 92
 - 3-6.2 Other Probability Plots 94

- 3-7 Discrete Random Variables 97
 - 3-7.1 Probability Mass Function 97
 - 3-7.2 Cumulative Distribution Function 98
 - 3-7.3 Mean and Variance 99
- 3-8 Binomial Distribution 102
- 3-9 Poisson Process 109
 - 3-9.1 Poisson Distribution 109
 - 3-9.2 Exponential Distribution 113
- 3-10 Normal Approximation to the Binomial and Poisson Distributions 119
- 3-11 More than One Random Variable and Independence 123
 - 3-11.1 Joint Distributions 123
 - 3-11.2 Independence 124
- 3-12 Functions of Random Variables 129
 - 3-12.1 Linear Functions of Independent Random Variables 130
 - 3-12.2 Linear Functions of Random Variables That Are Not Independent 131
 - 3-12.3 Nonlinear Functions of Independent Random Variables 133
- 3-13 Random Samples, Statistics, and the Central Limit Theorem 136

CHAPTER 4 Decision Making for a Single Sample 148

- 4-1 Statistical Inference 149
- 4-2 Point Estimation 150
- 4-3 Hypothesis Testing 156
 - 4-3.1 Statistical Hypotheses 156
 - 4-3.2 Testing Statistical Hypotheses 158
 - 4-3.3 *P*-Values in Hypothesis Testing 164
 - 4-3.4 One-Sided and Two-Sided Hypotheses 166
 - 4-3.5 General Procedure for Hypothesis Testing 167
- 4-4 Inference on the Mean of a Population, Variance Known 169
 - 4-4.1 Hypothesis Testing on the Mean 169

- 4-4.2 Type II Error and Choice of Sample Size 173
- 4-4.3 Large-Sample Test 177
- 4-4.4 Some Practical Comments on Hypothesis Testing 177
- 4-4.5 Confidence Interval on the Mean 178
- 4-4.6 General Method for Deriving a Confidence Interval 184
- 4-5 Inference on the Mean of a Population, Variance Unknown 186
 - 4-5.1 Hypothesis Testing on the Mean 187
 - 4-5.2 Type II Error and Choice of Sample Size 193
 - 4-5.3 Confidence Interval on the Mean 195
- 4-6 Inference on the Variance of a Normal Population 199
 - 4-6.1 Hypothesis Testing on the Variance of a Normal Population 199
 - 4-6.2 Confidence Interval on the Variance of a Normal Population 203
- 4-7 Inference on a Population Proportion 205
 - 4-7.1 Hypothesis Testing on a Binomial Proportion 205
 - 4-7.2 Type II Error and Choice of Sample Size 208
 - 4-7.3 Confidence Interval on a Binomial Proportion 210
- 4-8 Other Interval Estimates for a Single Sample 216
 - 4-8.1 Prediction Interval 216
 - 4-8.2 Tolerance Intervals for a Normal Distribution 217
- 4-9 Summary Tables of Inference Procedures for a Single Sample 219
- 4-10 Testing for Goodness of Fit 219

CHAPTER 5 Decision Making for Two Samples 230

- 5-1 Introduction 231
- 5-2 Inference on the Means of Two Populations, Variances Known 232
 - 5-2.1 Hypothesis Testing on the Difference in Means, Variances Known 233
 - 5-2.2 Type II Error and Choice of Sample Size 234

- 5-2.3 Confidence Interval on the Difference in Means, Variances Known 235
- 5-3 Inference on the Means of Two Populations, Variances Unknown 239
 - 5-3.1 Hypothesis Testing on the Difference in Means 239
 - 5-3.2 Type II Error and Choice of Sample Size 246
 - 5-3.3 Confidence Interval on the Difference in Means 247
- 5-4 The Paired t -Test 252
- 5-5 Inference on the Ratio of Variances of Two Normal Populations 259
 - 5-5.1 Hypothesis Testing on the Ratio of Two Variances 259
 - 5-5.2 Confidence Interval on the Ratio of Two Variances 263
- 5-6 Inference on Two Population Proportions 265
 - 5-6.1 Hypothesis Testing on the Equality of Two Binomial Proportions 265
 - 5-6.2 Type II Error and Choice of Sample Size 268
 - 5-6.3 Confidence Interval on the Difference in Binomial Proportions 269
- 5-7 Summary Tables for Inference Procedures for Two Samples 271
- 5-8 What if We Have More than Two Samples? 272
 - 5-8.1 Completely Randomized Experiment and Analysis of Variance 272
 - 5-8.2 Randomized Complete Block Experiment 281

CHAPTER 6 Building Empirical Models 298

- 6-1 Introduction to Empirical Models 299
- 6-2 Simple Linear Regression 304
 - 6-2.1 Least Squares Estimation 304
 - 6-2.2 Testing Hypotheses in Simple Linear Regression 312
 - 6-2.3 Confidence Intervals in Simple Linear Regression 315
 - 6-2.4 Prediction of a Future Observation 318
 - 6-2.5 Checking Model Adequacy 319
 - 6-2.6 Correlation and Regression 322
- 6-3 Multiple Regression 326
 - 6-3.1 Estimation of Parameters in Multiple Regression 326

6-3.2	Inferences in Multiple Regression	331
6-3.3	Checking Model Adequacy	336
6-4	Other Aspects of Regression	344
6-4.1	Polynomial Models	344
6-4.2	Categorical Regressors	346
6-4.3	Variable Selection Techniques	348

CHAPTER 7 Design of Engineering Experiments 360

7-1	The Strategy of Experimentation	361
7-2	Factorial Experiments	362
7-3	2^k Factorial Design	365
7-3.1	2^2 Design	366
7-3.2	Statistical Analysis	368
7-3.3	Residual Analysis and Model Checking	374
7-3.4	2^k Design for $k \geq 3$ Factors	376
7-3.5	Single Replicate of a 2^k Design	382
7-4	Center Points and Blocking in 2^k Designs	390
7-4.1	Addition of Center Points	390
7-4.2	Blocking and Confounding	393
7-5	Fractional Replication of a 2^k Design	398
7-5.1	One-Half Fraction of a 2^k Design	398
7-5.2	Smaller Fractions: 2^{k-p} Fractional Factorial Designs	404
7-6	Response Surface Methods and Designs	414
7-6.1	Method of Steepest Ascent	416
7-6.2	Analysis of a Second-Order Response Surface	418
7-7	Factorial Experiments With More Than Two Levels	424

CHAPTER 8 Statistical Process Control 438

- 8-1 Quality Improvement and Statistical Process Control 439
- 8-2 Introduction to Control Charts 440
 - 8-2.1 Basic Principles 440
 - 8-2.2 Design of a Control Chart 444
 - 8-2.3 Rational Subgroups 446
 - 8-2.4 Analysis of Patterns on Control Charts 447
- 8-3 \bar{X} and R Control Charts 449
- 8-4 Control Charts For Individual Measurements 456
- 8-5 Process Capability 461
- 8-6 Attribute Control Charts 465
 - 8-6.1 P Chart (Control Chart for Proportions) and nP Chart 465
 - 8-6.2 U Chart (Control Chart for Average Number of Defects per Unit) and C Chart 467
- 8-7 Control Chart Performance 470
- 8-8 Measurement Systems Capability 473

APPENDICES 483

APPENDIX A Statistical Tables and Charts 485

APPENDIX B Bibliography 500

APPENDIX C Answers to Selected Exercises 502

INDEX 511
