

# Contents

Preface	vii
I. Introduction	1
1. Random Vectors and Matrices	3
2. Multivariate Normal Distributions	4
3. Distributions of Quadratic Forms	7
4. Additional Exercises	11
II. Estimation	14
1. Estimability	15
2. Estimation: Least Squares	16
3. Estimation: Best Linear Unbiased	18
4. Estimation: Maximum Likelihood	19
5. Estimation: Minimum Variance Unbiased	20
6. Sampling Distributions of Estimates	21
7. Weighted Least Squares	22
8. Normal Equations	25
9. Additional Exercises	26
III. Testing Hypotheses	29
1. More About Models	29
2. Testing Models	31
3. Testing Linear Parametric Functions	38
4. Testing Single Degrees of Freedom in a Given Subspace	45
5. Discussion	46
6. Breaking a Sum of Squares into Independent Components	47

7. Confidence Regions	52
8. Tests for Weighted Least Squares Models	53
9. Additional Exercises	55
<b>IV. One-Way ANOVA</b>	<b>57</b>
1. Analysis of Variance	58
2. Estimating and Testing Contrasts	65
3. Additional Exercises	68
<b>V. Multiple Comparison Techniques</b>	<b>70</b>
1. Scheffe's Method	71
2. Least Significant Difference Method	75
3. Bonferroni Method	76
4. Tukey's Method	77
5. Multiple Range Tests: Newman-Keuls and Duncan	79
6. Summary	81
7. Additional Exercises	83
<b>VI. Regression Analysis</b>	<b>85</b>
1. Simple Linear Regression	86
2. Multiple Regression	87
3. Best Linear Prediction: Another Approach to Regression	93
4. The Multiple Correlation Coefficient and the Coefficient of Determination	97
5. Partial Correlation Coefficients	99
6. Pure Error and Lack of Fit	101
7. Polynomial Regression and One-Way Analysis of Variance	107
8. Additional Exercises	110
<b>VII. Multifactor Analysis of Variance</b>	<b>113</b>
1. Balanced Two-Way ANOVA Without Interaction	113
2. Balanced Two-Way ANOVA with Interaction	120
3. Polynomial Regression and the Balanced Two-Way ANOVA	129
4. Two-Way ANOVA with Unequal Numbers: Proportional Numbers	132
5. Two-Way ANOVA with Unequal Numbers: General Case	133
6. Three or More Way Analyses	141
7. Additional Exercises	149
<b>VIII. Experimental Design Models</b>	<b>151</b>
1. Completely Randomized Designs	152
2. Randomized Complete Block Designs: Usual Theory	152
3. Latin Square Designs	153
4. Factorial Treatment Structures	156
5. Additional Exercises	159

<b>IX. Analysis of Covariance</b>	<b>160</b>
1. Estimation of Fixed Effects	161
2. Estimation of Error and Tests of Hypothesis	163
3. Applications of Analysis of Covariance: Missing Data	166
4. Applications of Analysis of Covariance: Balanced Incomplete Block Designs	169
5. Additional Exercises	177
<b>X. Estimation and Testing in a General Gauss–Markov Model</b>	<b>179</b>
1. Best Linear Unbiased Estimation with an Arbitrary Covariance Matrix	180
2. Geometric Aspects of Estimation	185
3. Hypothesis Testing	189
4. Least Squares Consistent Estimation	194
<b>XI. Split Plot Models</b>	<b>201</b>
1. A Cluster Sampling Model	202
2. Generalized Split Plot Models	206
3. The Split Plot Design	214
4. Identifying the Appropriate Error	217
<b>XII. Mixed Models and Variance Components</b>	<b>223</b>
1. Mixed Models	223
2. Best Linear Unbiased Prediction	225
3. Mixed Model Equations	228
4. Variance Component Estimation: Maximum Likelihood	230
5. Maximum Likelihood Estimation for Singular Normal Distributions	234
6. Variance Component Estimation: Restricted Maximum Likelihood	235
7. Variance Component Estimation: MINQUE	237
8. Variance Component Estimation: MIVQUE	240
9. Variance Component Estimation: Henderson’s Method 3	240
<b>XIII. The Analysis of Residuals and Influential Observations in Regression</b>	<b>244</b>
1. Leverage	247
2. Checking Normality	257
3. Serial Correlation	261
4. Heteroscedasticity and Lack of Fit	264
5. Updating Formula and Predicted Residuals	273
6. Outliers and Influential Observations	276
7. Transformations	279
<b>XIV. Additional Topics in Regression: Variable Selection and Collinearity</b>	<b>282</b>
1. All Possible Regressions and Best Subset Regression	283
2. Stepwise Regression	286

3. Discussion of Variable Selection Techniques	289
4. Defining Collinearity	290
5. Regression in Canonical Form and on Principle Components	295
6. Classical Ridge Regression	298
7. More on Mean Squared Error	300
XV. Maximum Likelihood Theory for Log-Linear Models	302
1. Notation	302
2. Fixed Sample Size Properties	303
3. Asymptotic Properties	308
4. Applications	316
5. Proofs of Lemma 15.3.2 and Theorem 15.3.8	321
Appendix A: Vector Spaces	324
Appendix B: Matrices	329
Appendix C: Some Univariate Distributions	345
Appendix D: Multivariate Distributions	348
Appendix E: Tests and Confidence Intervals for Some One Parameter Problems	352
Appendix F: Approximate Methods for Unbalanced ANOVA's	357
Appendix G: Randomization Theory Models	361
References	368
Author Index	373
Subject Index	375