Contents

PART I. THE ANALYSIS OF VARIANCE IN THE CASE OF MODELS WITH FIXED EFFECTS AND INDEPENDENT OBSERVATIONS OF EQUAL VARIANCE

CHAPTER			PAGE
1	POINT ESTIMATION		
	1.1	Introduction	3
	1.2	Mathematical models	4
	1.3	Least-squares estimates and normal equations	8
	1.4	Estimable functions. The Gauss–Markoff theorem	13
	1.5	Reduction of the case where the observations have known correlations and known ratios of variances	19
	1.6	The canonical form of the underlying assumptions Ω. The mean square for error	21
		Problems	24
2	CONSTRUCTION OF CONFIDENCE ELLIPSOIDS AND TESTS IN THE GENERAL CASE UNDER NORMAL THEORY		
	2.1	Underlying assumptions Ω and distribution of point estimates under Ω	25
	2.2	Notation for certain tabled distributions	27
	2.3	Confidence ellipsoids and confidence intervals for estimable functions	28
	2.4	Test of hypothesis H derived from confidence ellipsoid	31
	2.5	Test derived from likelihood ratio. The statistic $\mathcal{F}$	32
	2.6	Canonical form of Ω and H. Distribution of $\mathcal{F}$	37
	2.7	Equivalence of the two tests	39
	2.8	Charts and tables for the power of the F-test	41
	2.9	Geometric interpretation of $\mathcal{F}$. Orthogonality relations	42
	2.10	Optimum properties of the F-test	46
		Problems	51

CHAPTER PAGE

3 THE ONE-WAY LAYOUT. MULTIPLE COMPARISON
3.1 The one-way layout 55
3.2 An illustration of the theory of estimable functions . . 60
3.3 An example of power calculations 62
3.4 Contrasts. The S-method of judging all contrasts . . 66
3.5 The S-method of multiple comparison, general case . . 68
3.6 The T-method of multiple comparison 73
3.7 Comparison of the S- and T-methods. Other multiple-comparison methods 75
3.8 Comparison of variances 83
Problems 87

4 THE COMPLETE TWO-, THREE-, AND HIGHER-WAY LAYOUTS. PARTITIONING A SUM OF SQUARES
4.1 The two-way layout. Interaction. 90
4.2 The two-way layout with one observation per cell . . 98
4.3 The two-way layout with equal numbers of observations in the cells 106
4.4 The two-way layout with unequal numbers of observations in the cells 112
4.5 The three-way layout 119
4.6 Formal analysis of variance. Partition of the total sum of squares 124
4.7 Partitioning a sum of squares more generally . . . 127
4.8 Interactions in the two-way layout with one observation per cell 129
Problems 137

5 SOME INCOMPLETE LAYOUTS: LATIN SQUARES, INCOMPLETE BLOCKS, AND NESTED DESIGNS
5.1 Latin squares 147
5.2 Incomplete blocks 160
5.3 Nested designs 178
Problems 188

6 THE ANALYSIS OF COVARIANCE
6.1 Introduction 192
6.2 Deriving the formulas for an analysis of covariance from those for a corresponding analysis of variance . . . 199
6.3 An example with one concomitant variable 207
6.4 An example with two concomitant variables . . . 209
6.5 Linear regression on controlled variables subject to error . 213
Problems 216

PART II. THE ANALYSIS OF VARIANCE IN THE CASE OF OTHER MODELS

CHAPTER PAGE

7 RANDOM-EFFECTS MODELS
- 7.1 Introduction . . . 221
- 7.2 The one-way layout . . . 221
- 7.3 Allocation of measurements . . . 236
- 7.4 The complete two-way layout . . . 238
- 7.5 The complete three- and higher-way layouts . . . 245
- 7.6 A nested design . . . 248
- Problems . . . 258

8 MIXED MODELS
- 8.1 A mixed model for the two-way layout . . . 261
- 8.2 Mixed models for higher-way layouts . . . 274
- Problems . . . 289

9 RANDOMIZATION MODELS
- 9.1 Randomized blocks: estimation . . . 291
- 9.2 Latin squares: estimation . . . 304
- 9.3 Permutation tests . . . 313
- Problems . . . 329

10 THE EFFECTS OF DEPARTURES FROM THE UNDERLYING ASSUMPTIONS
- 10.1 Introduction . . . 331
- 10.2 Some elementary calculations of the effects of departures . . . 334
- 10.3 More on the effects of nonnormality . . . 345
- 10.4 More on the effects of inequality of variance . . . 351
- 10.5 More on the effects of statistical dependence . . . 359
- 10.6 Conclusions . . . 360
- 10.7 Transformations of the observations . . . 364
- Problems . . . 368

APPENDICES
- I Vector algebra . . . 371
- Problems . . . 385
- II Matrix algebra . . . 387
- Problems . . . 401
- III Ellipsoids and their planes of support . . . 406
- Problems . . . 410

APPENDICES PAGE

IV Noncentral χ^2, F, and t 412
Problems 415
V The multivariate normal distribution 416
Problems 418
VI Cochran's theorem 419
Problems 423

F-TABLES 424

STUDENTIZED RANGE TABLES 434

PEARSON AND HARTLEY CHARTS FOR THE POWER OF THE F-TEST 438

FOX CHARTS FOR THE POWER OF THE F-TEST 446

AUTHOR INDEX AND BIBLIOGRAPHY 457

SUBJECT INDEX 467