Index

2^2 factorial design, 231
2^3 factorial design, 240
2^4 factorial design, 230, 252
2^{k-1} fractional factorial design, 329
2^{k-2} design, 344
2^{k-p} fractional factorial design, 351
3^2 factorial design, 406
3^3 factorial design, 407
3^4 factorial design, 405, 413
3^{k-1} fractional factorial design, 418
3^{k-p} fractional factorial designs, 431

A
Additivity of the Latin square, 154
Additivity of the RCBD, 145
Adjusted R^2, 265, 475
Agricultural era of experimentation, 19
Agricultural versus industrial experiments, 19
Alias matrix, 360, 427
Aliases, 330
Allowed-to-vary factors, 15
Alternate fraction, 331
Alternative hypothesis, 34
Analysis of combined array designs, 576
(online, Chapter 12)
Analysis of covariance as an alternative to blocking, 670, 679 (online, Chapter 15)
Analysis of covariance, 136, 670 (online, Chapter 15)
Analysis of variance (ANOVA), 67, 69, 73, 112
Analysis of variance identity for the RCBD, 138
Analysis of variance partition of the total sum of squares, 70
ANOVA F-test, 73
ANOVA method for estimating variance components, 113, 591
Approximate F-tests, 605
Assumptions in the t-test, 37

B
Balanced incomplete block designs (BIBD), 162
Bartlett’s test for equality of variances, 82
Bayesian D-optimal designs, 453
Best-guess approach to experimentation, 4
Blocking, 11, 12, 135, 153, 215, 308, 518
Blocking fractional factorials, 355, 367
Blocking in a 2^k design, 215, 308, 311
Blocking in response surface designs, 518
Box plot, 25, 66
Box-Behnken designs, 513
Box-Cox method for choosing a transformation, 657
(online, Chapter 15)
Break through innovation, 2

C
 Canonical form of the second-order model, 499
Cause-and-effect diagram, 16
Center points in the 2^k design, 285, 513
Central composite design (CCD), 288, 512, 513
Central limit theorem, 31
Chi-square distribution, 31
Chi-square test on the variance of a normal distribution, 53
Coding and natural variables, 236
Coded variables, 236, 290
Coding the data in ANOVA, 75
Column generators, 329, 344
Combined array designs, 572, 576
(online, Chapter 12)
Comparison of means, 88, 95
Complete randomization, 11
Completely randomized design, 68
Components of interaction, 408
Components of variance model, 68, 111
Confidence interval for a contrast, 91
Confidence interval on the mean response in regression, 478
(online, Chapter 10)
Confidence interval, 40, 41
Confidence intervals on means in ANOVA, 77
Confirmation runs, 18, 343
Confounding, 311, 320, 413
Constant variance assumption in ANOVA, 81
Constrained optimization, 508
Construction of optimal designs, 524
Contour plot, 499, 506
Contrasts, 89, 93
Controllable variables, 3
Cook’s distance, 483 (online, Chapter 10)
Corrected sum of squares, 29
Critical region, 34
Crossed array designs, 571 (online Chapter 12)
Crossover designs, 159

D
Defining relation for a fractional factorial, 329
Definitive screening designs, 530
Degrees of freedom, 31
Design factors, 15
Design generators, 344
Design projection, 258
Design resolution, 332
Designs with nested and factorial factors, 630
Desirability function optimization, 508
Deterministic computer models, 535
Dispersion effects, 109
Distance based designs for mixture experiments, 551
D−optimal designs, 281
Dot diagram, 24,
Dunnett’s test to compare means with a control, 98

E
Eigenvalues, 499
Empirical models, 2
Equiradial design, 515
Estimating variance components, 113
Estimator, 28
Evolutionary operation (EVOP), 553
Expected mean squares, 71, 112
Expected value of a random variable, 27
Experiments with computer models, 535
Extra sum of squares method, 476
Extreme vertices designs for mixture experiments, 551

F
Face-centered CCD, 514
Factor screening experiment, 13, 15
Factorial experiment, 4, 179
Factorial experiments with covariates, 682
(online, Chapter 15)
F−distribution, 33
First-order model, 17
Fisher’s least significant difference (LSD) method
to compare pairs of means, 97
Fixed effects model, 68
Fold over of fractional factorial designs, 364, 366, 377
Fold over of resolution III designs, 364, 366
Fraction of design space plot, 284, 517
Fractional factorial experiment, 7
Fractional factorial split-plot designs, 644
F−test on two variances of independent normal
distributions, 54
Full model, 121, 476

G
Gaussian process model, 537
Generalized interaction, 320, 344
Generalized linear model (GLM), 659
G−optimal designs, 282
Graeco-Latin square design, 160
Guidelines for designing experiments, 13

H
Half-normal probability plot, 261
Hall designs, 427
Held-constant factors, 15
Histogram, 25
Hybrid designs, 516
Hypothesis testing, 24, 33

I
Incremental innovation, 2
Influential observations in regression, 482
(online, Chapter 10)
Innovation and designed experiments, 2
Interaction, 17, 180
Interblock information in the BIBD, 169
Interpretation of ANOVA results, 87
I−optimal designs, 282

K
Kruskal-Wallis test, 123

L
Lack of fit testing in regression, 483 (online, Chapter 10)
Latin square designs, 153, 218
Lenth’s method, 262
Levene’s test for equality of variances, 83
Leverage points, 483
Linear predictor in the GLM, 660 (online, Chapter 15)
Linear statistical model, 68

M
Main effect of a factor, 17, 180
Mean of a distribution, 27
Means model, 67
Mechanistic models, 2
Method of least squares, 463
Method of steepest ascent, 239, 492
Minimal resolution IV designs, 376
Minimum variance estimator, 29
Missing values in the Latin square design, 157
Missing values in the RCBD, 149
Mixed level factorial designs, 422
Mixed models, 597
Mixture experiment, 10, 542
Multifactor split plot designs, 640
Multiple comparisons following ANOVA, 87, 93, 95, 142
Multiple response optimization, 506
N
Nested designs, 619
Nested designs with m stages, 628
No-confounding designs, 428
Nonregular fractional factorial design, 369, 425, 427, 436, 447
Normal distribution, 30
Normal probability plot, 37
Normal probability plot of residuals, 79
Normal probability plotting of effects, 254
Normality assumption in ANOVA, 79
Nuisance factors, 135
Null hypothesis, 34

O
One-factor-at-a-time (OFAT) approach to experimentation, 4
Operating characteristic curve, 42, 103
Optimal designs, 19, 280, 281, 282, 442, 522, 524
Optimal designs for mixture experiments, 547
Optimal designs for robustness studies, 582
Optimization experiment, 14
Orthogonal contrasts, 92
Orthogonal design, 233, 469
Outliers, 266, 480

P
Paired comparison design, 47, 52
Paired t-test, 47
Partial aliasing, 36
Partial confounding, 314, 323
Partial fold over, 381
Partial F-test, 477
Path of steepest ascent, 492
Plackett-Burman designs, 367
Power curve, 42, 103
Power family of transformations, 657 (online, Chapter 15)
Power of a test, 34
Prediction interval, 479
Prediction of new observations in regression, 479
(online, Chapter 10)
Pre-experimental planning, 17
PRESS statistic, 99, 482 (online, Chapter 10)
Principal block, 314, 321
Principal fraction, 330
Probability distributions, 26
Projection of fractional factorials, 354
Projection property, 329
P-value, 36

Q
Quantitative versus qualitative factors in ANOVA, 87

R
R², 474 (online, Chapter 10)
Random effects model, 68, 111, 589
Random error term, 67
Randomization, 11, 135
Randomization test, 39
Randomization tests and ANOVA, 76
Randomized complete block design (RCBD), 135, 136
Rank transformation in ANOVA, 124
RCBD with random treatments and blocks, 147
Reduced model, 122, 476
Reference distribution, 35
Regression approach to ANOVA, 119
Regression models, 87
REML method for estimating variance components, 118, 147, 595
Repeated measures designs, 692
Replicated design, 5
Replication versus repeat run, 12
Replication, 11
Residual plotting, 79, 81, 86, 145
Residuals, 79
Resolution III designs, 362
Resolution IV designs, 376
Resolution V designs, 383
Response surface, 206, 490
Response surface methodology, 490
Response surface models, 490
Response variable, 3
Restricted form of the mixed model, 597
Rising ridge systems, 506
Robust design, 20, 569
Rotatability, 512
Rotatable CCD, 513
R-student, 482 (online, Chapter 10)
Rules for expected mean squares, 602

S
Sample mean, 28
Sample size in ANOVA, 103
Sample standard deviation, 28
Sample variance, 28
Sampling distributions, 30
Scatter diagram, 66
Scheffé’s method for comparing all contrasts, 93
Scientific or engineering method, 2
Second-order model, 17
Sequences of fractional factorials, 341
Sequential experimentation, 14, 21, 341, 491
Signal-to-noise ratios, 573
Simplex centroid design, 542
Simplex design for fitting a first-order model, 511
Simplex designs for mixtures, 542
Simplex lattice design, 542
Single replicate of the 2² design, 254
Single-factor fold over, 364
Small composite designs, 515
Index

Space filling designs, 536
Space filling designs for mixture experiments, 551
Sparsity of effects principle, 329, 331
Spherical CCD, 513
Split-plot designs, 634
Split-split-plot designs, 645
Standard error, 35
Standard Latin square, 157
Standard normal distribution, 30
Standardized contrast, 91
Standardized residuals, 80, 480
Stationary point, 497
Stationary ridge systems, 505
Stochastic computer models, 535
Strategy of experimentation, 1, 3
Strip-split plot designs, 649
Studentized residuals, 481 (online, Chapter 10)
Subplot error, 635
Subplots or split-plots, 635
Supersaturated designs, 384

T

\( t \)-distribution, 32
Test statistic, 34
Testing significance of regression, 473
Tests on individual terms in regression, 475
Transformations, 657 (online, Chapter 15)
Tukey’s test to compare pairs of means, 95

Two-sample \( t \)-test, 35, 50
Two-sample \( t \)-test with unequal variances, 44
Two-stage nested designs, 619
Type I error, 34
Type II error, 34
Types of experiments, 13

U

Unbalanced data in a factorial, 666 (online, Chapter 15)
Unbalanced data in ANOVA, 78
Unbiased estimator, 29
Uncontrollable variables, 3
Unrestricted form of the mixed model, 599

V

Variance components, 111
Variance dispersion graph, 517
Variance of a distribution, 27
Variance stabilizing transformations, 82, 85, 657
(online, Chapter 15)

W

Whole plot error, 635
Whole plots, 635

Z

Z-test, 47