

References

- Adler, J. (2010). *R in a nutshell*. Sebastopol: O'Reilly Media.
- Allen, T. T. (2006). *Introduction to engineering statistics and six sigma*. London: Springer.
- Armitage, P. (1971). *Statistical methods in medical research*. Oxford: Blackwell Scientific Publications.
- Barker, T. B. (1990). *Engineering quality by design*. New York/Milwaukee: Marcel Dekker/Quality Press.
- Bickel, P. J., & Doksum, K. A. (2007). *Mathematical statistics: Basic ideas and selected topics* (2nd ed., Vol. 1). Upper Saddle River, NJ: Pearson Prentice Hall.
- Box, G. E. P., Hunter, W. G., & Hunter, J. S. (1978). *Statistics for experimenters*. New York: Wiley.
- Box, G. E. P., & Tiao, G. C. (1973). *Bayesian inference in statistical analysis*. New York: Wiley.
- Chow, S. C. (2007). *Statistical design and analysis of stability studies*. Boca Raton, FL: Chapman & Hall/CRC Press.
- Cochran, W. G., & Cox, D. R. (1992). *Experimental designs* (2nd ed.). New York: Wiley.
- Conover, W. J. (1999). *Practical nonparametric statistics* (3rd ed.). New York: Wiley.
- Cryer, J. D. (1986). *Time series analysis*. Boston: Duxbury Press.
- Desu, M. M., & Raghavarao, D. (1990). *Sample size methodology*. San Diego, CA: Academic.
- Draper, N. R., & Smith, H. (1998). *Applied regression analysis* (3rd ed.). New York: Wiley.
- Dunn, P. F. (2010). *Measurement and data analysis for engineering and science* (2nd ed.). Boca Raton, FL: Chapman & Hall/CRC Press.
- Efron, B. (1982). *The jackknife, the bootstrap, and other resampling plans*. Philadelphia: SIAM.
- Fleiss, J. L., Levin, B., & Paik, M. C. (2003). *Statistical methods for rates and proportions* (3rd ed.). New York: Wiley.
- Fowlkes, W. Y., & Creveling, C. M. (1995). *Engineering methods for robust product design*. Reading, MA: Addison-Wesley.
- Fries, A., & Hunter, W. G. (1980). Minimum aberration 2^{k-p} designs. *Technometrics*, 22, 601–608.
- Gelman, A., Carlin, J. B., Stern, H. S., & Rubin, D. B. (1997). *Bayesian data analysis*. Boca Raton, FL: Chapman & Hall/CRC Press.
- Grant, E. L., & Leavenworth, R. S. (1980). *Statistical quality control* (5th ed.). New York: McGraw-Hill.
- Hinkelmann, K., & Kempthorne, O. (2005). *Design and analysis of experiments: Vol. 2. Advanced experimental design*. Hoboken, NJ: Wiley.
- Hosmer, D. W., & Lemeshow, S. (1989). *Applied logistic regression*. New York: Wiley.
- Incropera, F. P., & De Witt, D. P. (1990). *Introduction to heat transfer* (2nd ed.). New York: Wiley.
- Johnson, N. L. (1949). Systems of frequency curves generated by translation. *Biometrika*, 36, 149–176.
- Johnson, N. L., Kotz, S., & Balakrishnan, N. (1995). *Continuous univariate distributions* (2nd ed., Vol. 2). New York: Wiley.
- Judge, G. G., Griffiths, W. E., Hill, R. C., Lütkepohl, H., & Lee, T. C. (1985). *The theory and practice of econometrics* (2nd ed.). New York: Wiley.
- Kacker, R. N., Lagergren, E. S., & Filliben, J. J. (1991). Taguchi's orthogonal arrays are classical designs of experiments. *Journal of Research of the National Institute of Standards and Technology*, 96(5), 577–591.
- Kaplan, E. L., & Meier, P. (1958). Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association*, 53, 457–481.
- Law, A. M., & Kelton, W. D. (1982). *Simulation modeling and analysis*. New York: McGraw-Hill.
- Lee, E. T. (1992). *Statistical methods for survival data analysis* (2nd ed.). New York: Wiley.
- Mann, N. R., Schafer, R. E., & Singpurwalla, N. D. (1974). *Methods for statistical analysis of reliability and life data*. New York: John Wiley and Sons.

- Meyer, P. L. (1970). *Introduction to probability and statistical applications* (2nd ed.). Boston: Addison-Wesley.
- Montgomery, D. C. (2001). *Design and analysis of experiments*. New York: Wiley.
- Nash, R. A., & Wachter, A. H. (2007). *Pharmaceutical process validation* (3rd ed.). New York: Informa Healthcare.
- Otto, K., & Wood, K. (2001). *Product design: Techniques in reverse engineering and New product development*. Upper Saddle River, NJ: Prentice-Hall.
- Pardo, S. A. (2009). A differential equation model for dissolution profiles, and its uses in designing dosage forms. *Statistics in Biopharmaceutical Research*, 1(2), 194–200.
- Pardo, S. A. (2014). *Equivalence and noninferiority tests for quality, manufacturing, and test engineers*. Boca Raton, FL: Chapman & Hall/CRC Press.
- Rutherford, E. (1900). A radioactive substance emitted from thorium compounds. *Philosophical Magazine Series 5, XLIX*, 1–14.
- Seber, G. A. F., & Wild, C. J. (1989). *Nonlinear regression*. New York: Wiley.
- Searle, S. R., Casella, G., & McCulloch, C. E. (2006). *Variance components*. New York: John Wiley and Sons.
- Smith, W. F. (2005). *Experimental design for formulation*. Philadelphia, PA: SIAM/ASA.
- Springer, M. D. (1979). *The algebra of random variables*. New York: Wiley.
- Taguchi, G., & Wu, Y. (1980). *Introduction to off-line quality control*. Nagoya: Central Japan Quality Control Association.
- White, G. W. (2012). The design of natural gas pipelines. *Pipeline and Gas Journal*, 239(9) (Sept. 2012), <http://pgjonline.com>.
- Whitten, K. W., Davis, R. E., Peck, M. L., & Stanley, G. G. (2004). *General chemistry* (7th ed.). Belmont, CA: Brooks/Cole.

Index

A

Accelerated life test, 175–179, 182
Acceptance criterion, 199
Accuracy, 11, 22, 209
Adjusted R^2 , 30, 31, 34, 37, 38, 44, 54, 75, 82, 105, 132
Alias structure, 64, 68, 76, 82, 90, 130, 209, 210
Aliasing, 60–61, 63, 65, 66, 69, 92, 99, 233
Alternate hypothesis, 8
Analysis of covariance (ANCOVA), 52
Analysis of variance (ANOVA), 15, 29–31, 34, 37, 38, 52, 132, 134, 157, 170
Analyte, 165
ANCOVA. *See* Analysis of covariance (ANCOVA)
Anderson-Darling, 97
ANOVA. *See* Analysis of variance (ANOVA)
App, 158–160, 162
Approximation, 13, 23–28, 30, 31, 37, 39, 41, 44, 46, 50, 56, 57, 59, 60, 70, 73, 148, 168, 169, 173–175, 189, 203, 204, 221, 225
Arrhenius, 175, 177, 178, 181, 183
Autocorrelated, 216, 218
Autocorrelation function (acf), 218, 220
Axial, 101
Axial points, 101, 104, 107, 112

B

Balance, 30, 42, 59, 60, 63, 73, 99
Ballistic, 102
Bath-tub, 166, 167
Bayes' theorem, 4, 5, 185, 196
Bayesian, 185
Bernoulli, 147, 198
Beta, 3, 185–187
Binary, 159
Bioreactor, 207–221
Biphasic, 140
Block, 68, 71, 74
Blocking, 71
Blocking effect, 71, 73
Boltzmann's constant, 176

Boot-strapping, 9

Box-Behnken designs (BBDs), 99, 101, 106–107, 112

Box-Cox, 96, 97

C

Capability, 9, 12, 31, 238
Cardiovert, 140
Catapult, 102–107
CCDs. *See* Central composite designs (CCDs)
Censoring, 174
Center point, 48, 56, 57, 93, 95, 96, 99, 101, 104, 107, 109, 112, 149, 204, 213, 215
Central composite designs (CCDs), 99, 101–107, 112, 140, 204
Central limit theorem, 9
Chemical, 42, 165, 175, 177, 178, 182
Chi-squared, 3, 14, 224, 225
Coefficient, 23, 24, 27, 29, 40–44, 49, 53, 54, 56, 59–61, 63, 73, 75, 82, 85, 96, 101, 105, 109, 114, 123, 132, 140, 149, 156, 157, 191, 194, 195, 204, 215, 216, 233
Coefficient of determination, 30
Collinearity, 60
Component, 37, 108, 113, 114, 123, 124, 140, 165, 168, 174, 175, 180, 182, 200, 209, 236–238
Concurrent, 224
Conditional density, 5, 185
Conditional expectation, 3, 5, 13, 16, 191
Conditional probability, 3–6, 12, 13, 19
Confidence, 9, 10, 14, 16, 19, 22, 33, 36–38, 50, 54, 57, 105, 112, 124–126, 128, 132, 143, 149, 150, 153, 158, 163, 170, 175, 180, 181, 189, 197, 198, 218, 224, 225, 238, 239
Confidence interval, 9, 10, 124, 163, 197
Conjugacy, 185
Conjugate pair, 185, 194, 196
Constraint, 26, 56, 57, 71, 79, 113, 114, 118–123
Contour, 105
Contour Profiler, 105
Control parameters, 223, 227–231, 235, 236, 239

Convection equation, 210, 213
 Corner points, 101, 112
 Covariance, 52
 Covariance matrix, 108, 150, 191, 194
 Covariate, 52
 C_p , 12, 20, 31, 34, 37
 Critical value, 34, 199, 229
 Cross-product, 39–42, 53, 57, 59–61, 63–66, 69, 70,
 73–76, 79, 81, 82, 85, 93, 108, 109, 115, 124, 130,
 132, 137
 Cumulative distribution, 2, 5, 166, 168, 182
 Cumulative failure rate, 167, 168
 Cumulative hazard, 167, 168, 182
 Cylinder, 170, 207, 209, 213

D

Data, 4, 5, 7, 9, 10, 14–16, 19, 20, 22–28, 30, 31, 33–44,
 46, 54, 56, 57, 60, 63, 70, 75, 76, 85, 90, 93, 95, 97,
 100, 105–107, 113–115, 117, 118, 122, 127, 132,
 133, 141, 143, 147, 149, 158, 169, 170, 176, 178,
 181–183, 185–189, 191, 195–198, 200, 201,
 204, 215, 216, 218, 221, 223, 225, 229–231,
 236, 238, 239
 Decibels, 224
 Defibrillator, 136, 140–142
 Defining contrasts, 233
 Defining relation, 66–69, 74, 93
 Degrees of freedom (*df*), 8, 9, 14, 15, 29, 30, 50, 96, 108,
 110, 135, 181, 197, 198, 200, 224, 225
 Density, 2, 3, 5, 7, 13, 98, 185–191, 203, 204
 Design, 11, 24, 37, 39, 41, 42, 44, 46, 52, 54, 57, 59–71,
 73–80, 83, 85–88, 90–93, 95, 99, 101, 104–110,
 112, 114, 115, 118, 123–124, 130–133, 138, 140,
 141, 143, 148, 149, 157, 165, 168–173, 181, 186,
 187, 191, 196, 198, 201, 204, 207–210, 216, 218,
 221, 223–225, 227–229, 231–239
 Desirability, 199–201
 Desirability Mapping, 199
 Deviance, 148
df. See Degrees of freedom (*df*)
 Differential equation, 165, 166, 182
 Dissolution, 229–231
 D-optimality, 124
 Dot product, 42

E

EASs. See Engineers and Applied Scientists (EASs)
 Effect, 30, 35, 40–42, 44, 50, 52, 56, 57, 59, 65, 68, 83,
 90, 92, 95, 130, 133, 140, 170, 173, 204, 213–216,
 224, 232, 236
 EML. See Empirical maximum likelihood (EML)
 EML with right-censoring (EMLC), 174, 175
 EMLC. See EML with right-censoring (EMLC)
 Empirical, 10, 23–28, 37, 38, 113, 168–169, 174, 196
 Empirical maximum likelihood (EML), 168, 174, 175
 Energy of activation, 176, 177

Engineers and Applied Scientists (EASs), 10, 11, 22–27,
 30, 31, 33–39, 42, 46, 48, 50, 52, 56, 65, 71, 74, 76,
 83, 85, 90, 95, 96, 99, 102, 105, 108, 113, 114, 129,
 140, 148, 149, 156–158, 165, 168, 169, 174,
 175, 177, 178, 181, 182, 186–189, 191, 195,
 197, 198, 200, 203, 204, 207, 209, 213, 215,
 227–230, 236, 239
 Epoxy, 24, 25, 27, 197
 Equivalence, 201, 232
 Event, 1, 3–6, 13, 140, 145, 165, 166, 182
 Expectation, 2, 9, 169, 186
 Expected value, 3, 5–10, 12, 31, 186, 187, 191, 224
 Experiment, 1, 3, 23–28, 33–35, 37, 39, 41–44, 46,
 48, 52–54, 56, 57, 59–61, 64, 66, 70, 71, 73–75,
 77, 81–83, 85–88, 90–93, 95, 96, 99, 101, 104,
 106, 108, 109, 112–115, 118, 122, 124, 126,
 128–130, 132–134, 139, 140, 143, 158,
 168–170, 173, 176–178, 182, 188, 191,
 198, 204, 206, 207, 209, 215, 218, 221,
 223, 227, 229–233, 235, 238
 Exponential, 166, 176–178, 182
 Exponential time-to-failure, 166

F

F distribution, 29, 30, 135, 225, 226, 229
 F ratio, 29, 30, 34
 FACTEX, 68, 70–72, 84, 234, 235
 Factor, 23, 37, 39–44, 46, 48–50, 52–54, 56, 57, 59–61,
 64–71, 73–76, 82, 85, 90, 92, 93, 95, 97, 99, 101,
 102, 104–107, 109, 112, 115, 118, 124, 125, 129,
 130, 132, 139, 140, 148, 149, 156–158, 169, 170,
 173, 175, 180, 198, 204, 209, 213, 215, 218, 221,
 227, 228, 232–235, 238, 239
 Factorial, 23, 37, 39, 52, 54, 57, 59–64, 67, 68, 71, 73, 83,
 84, 92, 95, 101, 112–115, 130–143, 169, 204,
 207–209, 228, 231, 232, 238
 Failure rate, 166–168, 175–178, 183
 Fibrillation, 136, 139
 Force, 24, 25, 29, 33, 75, 81, 130, 135, 148, 204–208, 221,
 229, 230
 Formulation, 113, 119, 182, 196
 Fractional, 93
 Fractional factorial, 93, 95, 101, 209, 227, 228,
 232, 238
 Full factorial, 59, 60, 64, 204, 207, 208,
 227, 228

G

Gamma, 3, 169, 189, 194
 Gauge, 11
 Gaussian, 27, 29, 31, 108
 Generator, 62, 64, 66, 68, 74, 76, 85, 232
 Genmod, 149, 154, 155, 158–160
 GLM, 80
 Goodness-of-fit, 99, 100
 G-optimality, 124

H

Hazard rate, 166, 182
 Heat conduction, 209
 Heat transfer, 207–221
 Helmert, 68
 Helmert coding, 41, 42, 44, 46, 48, 49, 54, 56, 60, 61, 64, 74, 85, 90, 93, 101, 102, 104, 108, 109, 132, 138, 140, 149, 204, 207, 209, 213, 221, 228, 234
 Heteroscedasticity, 30, 95–98, 100
 Higher order, 23, 46, 48, 56, 57, 59, 61, 70, 112
 Highest-is-best, 199
 Hip joint, 169
 Histogram, 31, 97, 98, 100, 204, 206
 Honestly significant difference (HSD), 50, 51, 132, 137
 Hyperparameter, 185, 186, 188, 189, 191, 195
 Hypothesis, 7–10, 14, 44, 97, 108–112, 135, 199, 225, 229
 Hypothesis test, 9, 10, 110

I

Ideal gas law, 221
 Identity, 62, 64–66, 68
 Impedance, 227, 236
 Inconsistent, 122, 123
 Independence, 3
 Inference, 7, 8, 10
 Information, 56, 59, 60, 63, 73, 76, 150, 178, 196, 216
 Information matrix, 150
 Initial condition, 83, 165, 166
 Inner array, 227, 229, 231, 239
 Input, 15, 17, 23, 36, 37, 39–42, 44, 46, 48, 52, 54, 56, 61, 63, 81, 83, 178, 197, 201, 204, 208, 218
 Interaction, 44, 50, 54, 56, 57, 59, 61, 71, 75, 90, 132, 170, 173
 Interaction plot, 132, 136
 Inverse, 54, 109, 150, 157, 163, 181
 Inverse regression, 125, 126
 I-optimality, 124

J

JMP, 44, 45, 54, 69, 73, 75–78, 82, 85–87, 97, 105, 118, 124, 132, 140, 159, 170, 214, 216, 217, 220, 227, 234, 236, 237
 Johnson, N.L., 97, 99, 100, 108, 224, 225
 Joint probability, 3–5, 12

K

Kaplan-Meier (K-M), 174, 175
 Kinetics, 165, 167, 182
 Kolmogorov-Smirnov, 97

L

Lag, 218
 Law of the Unconscious Statistician, 203
 Least squares, 25, 27, 37, 38, 42–44, 53, 60, 127, 169, 182, 195, 238

Least upper bound, 199
 2-level array, 232, 233
 3-level array, 232
 Life testing, 165–183
 LiI, 1
 Likelihood function, 147, 185, 191, 195, 196
 Log odds, 157–159, 162
 Logistic, 148, 149, 157, 163
 Logistic regression, 163
 Logit, 146–149, 153, 155–157, 161–163
 Loss, 63, 165, 223–229, 231, 238, 239
 Lowest-is-best, 199

M

Maclaurin, 24
 Main effect, 41, 90, 130, 132, 133, 140, 213, 214, 216, 221
 Mallow, 31, 34, 37
 Mangonal, 102–104
 Markov chain, 191, 196
 Mass function, 3
 Matrix, 33, 53–54, 60, 63, 90, 101, 108, 109, 124, 150, 191
 Maximum likelihood, 147, 157
 MCMC. *See* Monte Carlo Markov Chain (MCMC) 195
 Mean, 135, 139, 231
 Mean square error (MSE), 31, 198
 Measurement systems analysis (MSA), 11–21
 Medieval, 102
 Minitab, 15, 17–19, 44, 46, 67–70, 75, 82, 83, 97, 109, 130, 209, 234, 235
 Mixed-level array, 232, 234–236
 Mixture, 124
 Model, 23, 26–42, 44–50, 52–57, 59–61, 63, 65, 66, 69, 70, 73–75, 77–83, 85–88, 92, 93, 95–97, 99, 105–112, 114–119, 124–127, 132, 133, 140–143, 148, 149, 159, 162, 165–169, 173, 175, 180, 182, 195, 197, 198, 201, 204, 209, 213, 215–221, 223, 233, 236–238
 Moment, 2, 3, 148, 223, 238
 Monophasic, 140
 Monte Carlo, 191, 204, 218
 Monte Carlo Markov Chain (MCMC), 191–196
 MSE. *See* Mean square error (MSE)
 Multiple comparison tests, 50
 Multiple regression, 23, 138, 148
 Multivariate, 199, 201
 Mutual exclusivity, 3

N

*n*cp. *See* Non-centrality parameter (ncp) 110
 Newton-meters (Nm), 188, 189
 Newton-Raphson, 37, 148
 Nm. *See* Newton-meters (Nm) 189
 Noise, 25–27, 29–31, 39, 53, 57, 83, 96, 97, 108, 132, 170, 180, 195, 208, 213, 215, 216, 218, 223, 224, 227–229, 231, 236, 238, 239

Noise parameters, 223, 227–229, 231, 239
 Non-central, 8
 Non-central Chi-squared, 224, 225
 Non-central F, 225, 226, 229
 Non-central t, 8, 108, 110
 Non-centrality parameter (*ncp*), 8, 108, 110, 224, 225
 Non-inferiority, 199, 201
 Non-linear, 23, 148
 Nonlinear program, 118
 Normal, 3, 7, 12–14, 27, 96–98, 185, 186, 188–189, 191, 195, 204, 221
 Normal distribution, 97, 186, 191
 Normality, 95–100
 Null, 7, 8, 10
 Null hypothesis, 7, 9, 10, 97, 108, 110, 135, 199, 225, 229
 Numerical precision, 22, 191, 209
 Nusselt, 213

O

Objective function, 37, 118
 Observations, 4, 7, 10, 23, 29–31, 33–35, 37, 38, 40, 42, 108, 115, 128, 148, 150, 174, 175, 185, 196, 199, 225, 228, 229
 OC curve, 110
 Occam, 30
 Ockham, W., 30, 37, 38, 61, 63, 65, 74, 115, 140
 Octane, 114–116, 118–120, 122
 Odds, 145–146, 157, 162, 163
 Odds ratio, 146, 157, 158, 163
 Ohm, 140
 Ohm's law, 135, 139
 Operating characteristic (OC), 110
 Optimal design, 123–124
 Optimality, 123, 124
 Optimization, 37, 118, 122, 143, 201, 216, 220, 227, 239
 Order, 11, 22–24, 26, 30–32, 34–39, 41, 42, 44–47, 49, 55, 99, 106, 114–115, 120, 122, 123, 170, 209
 1st-order, 57, 60, 61, 63, 92, 95, 114, 115, 118, 125, 198, 221
 2nd-order, 31, 60, 62–66, 93, 95, 112, 124, 140, 204, 213, 215, 216, 221, 238
 2nd-Order, 115–120, 122, 123, 141, 142, 215, 217, 219, 220
 Order statistics, 168, 174
 Orthogonal array, 223, 227, 232–235, 238
 Orthogonality, 42, 59, 60, 63, 73, 99
 Outcome, 1, 3, 29, 140, 145, 232
 Outer array, 227–229, 231, 239
 Outlier, 38, 95
 Outputs, 23, 37, 46

P

Parameter design, 227–229, 235, 239
 Parameters, 2–5, 7–11, 13, 19, 20, 23, 29–31, 37, 38, 44, 50, 54, 56, 83, 90, 97, 108–112, 114, 115, 124, 147, 148, 156, 162, 165, 166, 168–173, 176–179, 181, 182, 185, 186, 188, 189, 191, 194–196, 200, 204, 208, 209, 213, 218, 223–225, 227–232, 235, 236, 238, 239

Parametric, 3, 5, 196
 Parsimony, 30, 37, 38, 75
 PBD. *See* Plackett-Burman designs (PBD)
 pdf. *See* Probability density function (pdf)
 Pipeline, 149
 Plackett-Burman, 90–93
 Plackett-Burman designs (PBD), 90, 92
 pmf. *See* Probability mass function (pmf)
 Point estimate, 9, 19, 126, 128, 129
 Poisson, 3, 166
 Polynomial, 23–28, 30, 31, 33, 37–39, 44, 46, 50, 54, 56, 57, 59, 112, 126, 127, 168, 169, 173, 175, 180, 183, 201, 223, 228, 238
 Population, 7, 8, 10, 97, 158
 Posterior, 185–189, 191, 194–196, 204
 Posterior density, 185, 187–191, 194
 Power, 8, 71, 90, 108, 110, 126, 135, 139, 208, 209, 232
 Power curve, 8, 110, 111
 Precision, 9–11, 22, 35
 Predicted value, 27, 31, 33–35, 37, 38, 44, 48, 53, 54, 56, 75, 95, 96, 99, 105, 118, 124, 125, 129, 132, 143, 149, 153, 156, 170, 175, 180, 181, 197, 198
 Prediction, 27, 28, 32, 33, 35, 36, 46, 54, 56, 105, 107, 122, 180, 197, 201
 Prediction interval, 180
 Principal fraction, 74, 233
 Prior, 4, 73, 82, 185–191, 193–196, 218, 229
 Prior density, 185–191, 194
 Probability density function (pdf), 2
 Probability mass function (pmf), 2
 Profiler, 119, 220
 Projectile, 102, 103, 105
 Prototype, 83, 132, 148, 158, 169, 178, 182, 206, 218
 p-value, 8, 22, 29, 44, 52, 54, 75, 82, 97, 132, 135, 170

Q

Quadratic, 31, 33, 95, 99, 101, 115, 126–129
 Quadratic loss function, 224, 238
 Quality, 11, 69, 114, 178, 180, 182, 223

R

Radioactive, 165, 182
 Random variable, 1–3, 5, 7–10, 96, 147, 166–167, 185–186, 198, 203–221
 Range finding, 125–127, 198
 Reduced model, 54–56, 75, 78–80, 82–83, 87–88, 138, 219
 Reference, 11–15, 165
 Reference method, 11, 15–21
 Regression, 19, 21, 23, 25, 35, 38, 52, 83, 110, 125–128, 132, 138, 145–163, 178, 180–182, 191, 195, 214
 Regressors, 23, 30, 50, 108, 112, 126–127, 129, 138, 140, 147–157, 159, 161, 162, 180, 191, 198–200, 204, 228
 Reliability, 165–183, 198
 REML. *See* Restricted Maximum Likelihood (REML)
 Replicate, 26–28, 42, 46, 48, 56, 74, 85, 95, 101, 104, 107–109, 114, 132–133, 140, 149, 213, 215–216, 239

Replication, 59, 92, 95, 101, 109, 182
 Residuals, 31–32, 44, 95–97, 132, 134, 170, 213, 236–238
 ResIII, 59, 65–66, 70, 73, 90–92, 209
 Resistance, 90, 105, 135–136, 139–140
 ResIV, 59, 65, 69–71, 73, 76–83, 86–88
 Resolution, 59–60, 65–67, 69–70, 73, 93, 130, 227–228, 233
 Response, 23, 39, 59, 95, 113, 125, 148, 165, 191, 197, 213, 231
 Restricted Maximum Likelihood (REML), 236
 ResV, 59, 62–63, 70, 73–80, 83, 93
 RLC circuit, 83
 Robust Design, 223–239
 Root mean square, 31, 35, 44, 54, 108, 127, 180, 198, 225
 Root mean square error (RMSE), 31, 125, 127–128, 198
 Rotatability, 99–101
 Run, 25, 41, 56, 59, 95, 132, 149, 168, 191, 204, 227

S

Sample, 1, 4–5, 7–11, 14, 22, 30–32, 36–37, 57, 135, 147, 158, 174, 182, 186, 188, 191, 197, 200, 216, 218, 224–225
 Sample size, 9, 10, 31, 57, 158, 186, 197
 Sample space, 1, 4–5, 7
 Sample statistic, 7–8, 22, 32, 225
 SAS, 44, 47, 68–71, 75–76, 80, 82, 84, 88, 114–117, 119, 149, 154–155, 158–160, 234–235
 S_B , 97, 99
 Science, 37
 Screening design, 69, 85
 Std Error (SE), 32–33, 35, 44, 54, 101, 107–109, 126, 128, 135–137, 150, 153, 175, 180, 209
 Seed, 6, 90, 92, 207
 Sensor, 139, 207–209, 215
 Sets, 3–5, 123, 174, 186, 231
 Shapiro-Wilk, 97, 98
 Shelf Life, 165–182
 Signal-to-noise ratio (SNR), 223, 224, 231, 238
 Simplex, 113
 Simulation, 175, 196, 203–220
 Six Sigma, vi, 230
 Slope, 40, 41, 50, 181, 195
 SNR. *See* Signal-to-noise ratio (SNR)
 Solver, 18, 33, 129, 130, 156
 Specification, 11, 12, 14, 15, 20, 27, 33–36, 114, 157, 177, 181, 204, 209, 213, 237
 Sum of squared errors (SSE), 29–31, 53
 Stability, 178–182
 Standard deviation, 2, 3, 9, 11, 27, 30, 31, 34, 36, 95–97, 108, 133, 139, 170, 188, 200, 204, 206, 236
 Studentized, 95, 96
 Student's t , 3, 8, 9, 33, 108, 110, 125, 128, 181, 198, 200
 S_U , 99
 Supernum (*Sup*), 199
 Survival, 178

T

t distribution, 8, 9, 33, 96, 108, 110, 127, 181, 197, 200
 t test, 157
 Taguchi, 223–239
 Target-is-best, 199, 200
 Taylor, 24, 26–28, 37
 Temperature, 4, 42, 46, 48, 52, 56, 176–178, 181, 182, 207–209, 213, 215, 216, 218, 229, 230
 Thermal regulation, 207–209
 Time Series, 216, 218
 Time-to-event, 165, 182
 Tolerance Design, 235–239
 Tolerance range, 197, 204
 Torque, 188
 Transformation, 23, 41, 96, 97, 99, 146–148, 153, 157, 162, 238
 Transpose, 33
 Truth, 10, 11, 30
 Tukey, 50–52, 137
 Tukey HSD, 50, 137
 Tukey-Kramer, 50
 Type I censoring, 174
 Type I risk, 8
 Type II censoring, 174
 Type II risk, 8

U

Unconscious Statistician, Law of, 203
 Uniform, 203
 Union, 3
 Updating, 191, 194, 195

V

Validation, 34, 197–200
 Variability, 11–13, 31, 37, 140, 197, 204, 224, 231, 236, 239
 Variance, 2, 29, 30, 96, 97, 100
 Variance Components, 237–238
 Variation, 11, 12, 16, 29–33, 35, 37, 125, 227, 230, 235, 239
 Vector, 42, 53, 54, 108, 148, 149, 178, 191, 194, 197–200, 218, 233
 Ventricular fibrillation (VF), 139, 140, 197–200
 Verification, 33–36
 Voltage, 1, 83, 90, 135, 139
 V-Optimality, 124

W

Warranty, 180, 181
 Weibull, 182
 Word, 14, 16, 24, 33, 36, 62, 65–71, 74, 104, 113, 158, 186, 198, 199, 236