

## Index

- acceptance sampling vs conformity assessment, 166
- accuracy and exactness, statistical, 18, 48, 96, 112
- accuracy, in measurement, 7, 9, 67, 204, 214
- ‘all models are wrong’, 196
- American Institute of Aeronautics and Astronautics, 242
- American Society of Mechanical Engineers, 242
- ancillary variate, 78
- assurance, 3, 20, 45, 86, 249, 253, 257
  - postmeasurement, 51, 198, 249, 250, 257
  - premeasurement, 51, 198, 249, 257
- auxiliary variate, 78
  
- Bayes’ theorem, 207–209, 213, 235, 236
- Bayesian statistics, 5, 22, 40, 51, 90, 117, 206–214, 239, 240, 243, 244
  - anticipated success rate in, 86, 210, 234
  - coherence of, 212, 222–227
  - controversial nature of, xii, 209
  - frequency-based, 213
  - meaning of output of, 257
  - objective, 96, 212, 213, 220–236, 250–252
  - simultaneous inference in, 184
  - subjective, 210–212, 214, 228
  - view of probability, 32, 86, 209–210
- bias, 10, 21, 60, 111, 131, 142, 192, 198, 255
  - adjustment for, 126, 129, 135, 201
  - as a term, xvii
  - definition of, xvii
  - estimation of, 198–200
  - experimental, 192, 201–202
- Bonferroni inequality, 141, 182–184, 195
- Bureau International des Poids et Mesures, 57, 237
  
- calibration, 22, 24, 29, 30, 59, 61, 161, 189–191
  - of measurement technique, 201
- categorical variable, as basis of entropy, 231, 232
- central limit theorem, 9, 103
  - for identical variables, 52
  - for non-identical variables, 24, 53, 54, 65, 67, 104
- cherry picking, 144, 184, 255
  
- classical statistics, *see* frequentist statistics
  - extended, xv, 73, 81, 258
- coherence, *see* Bayesian statistics
- combination of data, 254–256
- compound distribution, 114–117
- confidence, 32, 38, 45–52, 86, 216, 257, 258
  - as a term, 45
  - average, 25, 29, 55, 72, 73, 80
  - conditional, 77–80
  - level of, 22, 49, 55, 88, 118, 182–184, 216
- confidence band, 187, 188
- confidence belt, 247, 248, 250
- confidence coefficient, *see* confidence, level of
- confidence interval, 32, 40, 45–50, 214
  - approximate, definition of, 49
  - as a procedure, 46, 93, 112, 198, 247
  - as a term, 31, 46
  - as random entity, 46, 215
  - average, 72, 87, 103, 125, 135, 145–150, 213
  - definition of, 74
  - conditional, 72, 77–80, 87, 103, 125, 150, 200
  - definition of, 78
  - definition of, 48, 86
  - exact, definition of, 48
  - found from hypothesis tests, 184, 197, 247
  - left-infinite, 87
  - logical basis of, 5, 85
  - practical implication of, 46, 62
  - preferred to credible interval, 51, 236
  - realized, definition of, 46
  - right-infinite, 87
  - simultaneous, 179–184
  - type relevant to status of unknowns, 13
  - valid, definition of, 48
  - vs probability interval, 215
- confidence region, 175–183, 187–189, 229, 266
- conformity assessment vs acceptance sampling, 166
- conservatism, statistical, 48, 67, 70, 97, 149, 169, 180, 184, 263
- consistency, test of, 193–195, 200, 203

- consistent gambler, 33, 34, 36, 220, 223, 246
- constrained target value, 19, 51, 198, 230, 245–258
- correlation, 158, 162, 164
- correlation coefficient, 101
- covariance matrix, 104, 154–164, 176, 177, 229
- credible interval, 5, 51, 210, 214, 235, 236, 251
  - definition of, 208
- credible, as a term, 45
- credible region, 229
- cumulants, 105–107
- cumulants method, 117–121, 135, 140, 143, 264
- data snooping, 184
- decision theory, 52
- degree of belief, 32, 209–212, 239, 241, 260
  - definition of, 34, 38, 220
  - frequentist concept of, 239, 244
  - long-run requirement for, 35, 86
  - vs probability, 38
- degrees of freedom, effective number of, 49, 93, 97, 118
- digitization, *see* discretization
- discretization, 25, 29, 74–76, 224
- distributed-measurand concept, 207, 238–241
- distribution
  - arc-sine, 106, 107, 122, 263
  - beta, 67, 107, 118, 264
  - bivariate normal, 177
  - chi-square, 95, 107, 216
  - exponential, 53, 70, 205
  - $F$ , 107, 177, 188
  - Hotelling's  $T^2$ , 176–180, 229
  - Laplace, 53, 106
  - maximal variance, 67–69
  - multivariate normal, 176, 180, 181, 229
  - non-central chi-square, 136, 144
  - normal, 9, 24, 42, 43, 52, 67, 92, 95, 106, 118, 123, 140, 233, 261, 263, 264
    - standard, 52, 96, 107, 108, 122, 168, 247, 261
    - truncated, 69, 70, 224–226, 251
  - Pearson, 107–111, 116, 118, 121, 264
  - raised cosine, 67, 68
  - Student's  $t$ , 48, 53, 92, 94–97, 105–107, 116, 123, 263
    - truncated, 117, 227
  - triangular, 66, 106, 113, 115
  - uniform, 42, 53, 62, 64, 66, 68, 75, 93, 105–108, 110, 115, 122, 138, 181, 222, 224, 261–265
- efficiency, statistical, 50, 94, 140, 141, 175, 178, 184
- entropy, 67, 230–233, 240
  - as information rate, 231
  - meaning with categorical variables, 232
  - meaning with numerical variables, 232
- environmental quantity, 13, 26, 27, 39, 41, 61, 78–80, 87, 103, 150
- error
  - calibration, 24, 29, 69
  - classification of, 28–30, 237
  - definition of, 7
  - discretization, 25, 29, 74
  - fixed, definition of, 29
  - inhomogeneity, 24
  - linearization, 27, 112
  - 'linearized', 105, 117, 118, 120, 123
  - matching, 25, 28, 132, 145
  - moving, 29, 30, 57, 60, 170, 171
  - multiplicative, 229
  - numerical vs 'random', 31
  - propagation of, 57, 101, 152, 154, 157, 237
  - pure, 24, 26, 27
  - random, definition of, 28
  - sampling, 21, 24, 30
  - specification, 27
  - statistical, 21, 23, 26, 28, 30
  - systematic, definition of, 28
  - time-scale for, 169–171
  - Type A, 30, 93, 97, 116, 117, 124, 262, 263
  - Type B, 30, 93, 97, 114, 117, 262, 263
    - estimation of total, 192, 198–200, 203
  - vs uncertainty, as a term, 257
- error analysis, the subject of, 9, 16, 56, 86
- estimate equation
  - definition of, 14
  - linear approximation to, *see* linear approximation
- estimate, as a term, xvii
- estimation vs prediction, 6
- estimator
  - conditional/unconditional, 199
  - consistent, 96
  - interval, 47, 103
  - linear, 199
  - point, 79
  - vs estimate, 40
- estimator equation, example of, 140
- excess, coefficient of, 105–119, 265
  - definition of, 105
  - interval length related to sign of, 110, 114
  - of compound distribution, 115
  - of familiar distributions, 105, 106
  - of symmetric Pearson distributions, 108
  - of  $t$  distributions, 116
  - propagation of, 107
- expected value, 34, 42, 86, 209, 239, 259, 260
- experiment equation, definition of, 12
- experiment vs measurement, 57, 59–62
- experimental uncertainty, 249, 255–257
  - as measurement uncertainty, 256
- fiducial inference, 205–207, 239, 243
- Fisher, R. A., Sir, 52, 205, 206, 235
- fixed estimate, 22, 25, 39, 77, 102, 130–135, 145–147, 150
- fluctuating quantity, 6, 12, 26, 78, 244
- frequentist statistics
  - as 'classical' statistics, 21

- concept of 'degree of belief' in, 210
- extended, xv, 73, 81, 258
- in revision of the *Guide*, 243
- practical, 47, 73, 76
- textbook, 73, 76, 204, 206, 249
- view of probability, 32, 35
- function estimation, 6, 161, 185–191
  
- Gauss, C. F., 235
- goodness-of-fit test, 192, 196–197
- Guide to the Expression of Uncertainty in Measurement*, xii, 5, 13, 18, 29, 58, 93, 97, 118, 148, 237–244
  
- hypothesis, simple, 196
- hypothesis test, 51, 167, 182, 184, 193, 196, 197, 200
  - as detection, not measurement, 253
  - inversion to obtain a confidence interval, 184, 197, 247
  
- ignorance, intention to quantify, 222, 227–230
- indication, as a term, 244
- inference, statistical, definition of, 45
- information, 17, 28, 50, 51, 208, 220, 230–233
  - as a term, 221
  - as an objective concept, 212, 220–221
  - contained in ordering and distance, 232
  - rate of gain of, 231
  - vs information rate, 231
- input quantity, as a term, 241, 244
- Intergovernmental Panel on Climate Change, 242
- International Vocabulary of Metrology*, xvii, 5, 17, 214
- interval
  - confidence, definition of, 48, 86
  - credible, definition of, 208
  - prediction, example of, 189
  - probability, definition of, 215
  - tolerance, definition of, 216
  
- kurtosis, 105, 123
  
- Laplace, P.-S., 235
- least squares, 187
- likelihood function, 208, 211
- linear approximation, 27, 98–125, 128–132, 136, 144, 157
  
- mathematical expectation, *see* expected value
- measurand
  - definition of, xv, 5
  - identification of, 10–12
- measurand equation, 12–16
  - as an approximation, 14, 27
  - contribution to error, 27
  - decomposition of, 15, 130
  - definition of, 12
  - implicit, 15, 111
  - linear approximation to, *see* linear approximation
- measurement comparison, 192–203, 254
- measurement error
  - as secondary concept for a statistician, 21
  - definition of, 7, 85
- measurement estimate, definition of, 7
- measurement result, definition of, 7
- measurement vs experiment, 57, 59–62
- measurement, goal of, 4, 20
- model
  - approximate nature of, xiv, 14, 27, 49, 196
  - inadequacy of, 254
  - of measurement, 16, 88–90
  - purpose of, 185
  - statistical/probabilistic, 14, 38, 43–45
  - subject of, 38
- Monte Carlo analysis, 55, 88, 97, 98, 151, 181
- Monte Carlo estimation of quantile, 120
- Monte Carlo evaluation of distribution, 53, 110, 120–124, 182, 184
- Monte Carlo integration, 54
- Monte Carlo simulation, *see* simulation of the measurement
- multiple comparisons, 182
  
- Neyman, J., 51, 52, 205
- non-linear function, 27, 125–151
- normal-approximation method, 105, 114, 116–119, 135, 140, 143
- notation, xiv, 14, 39–41
  - non-standard, 44, 106
  - postmeasurement, 43, 85, 89, 90, 103, 158
  - premeasurement, 43, 85, 89, 90, 194
  - statistical vs non-statistical, 41
  
- observation, as a term, 244
  
- parameter
  - definition of, 13
  - estimation of, xii, xiv, xvii, 6, 12, 47, 87
  - of the experiment, 13
- parent, as a term, 44, 90
- Pearson system of distributions, 107–109
- Pearson, E., 51, 52
- Pearson, K., 107
- Popper, K. Sir, 37
- posterior distribution, 208, 222, 234, 252
  - marginal, 230
  - predictive, 225
- prediction interval, 189
- prediction vs estimation, 6
- predictive distribution, 224, 225
- principle of maximum entropy, 67, 231–233, 240
- prior distribution, 76, 205, 208, 209, 229, 235
  - as an inconvenience, 236
  - elicitation of, 211
  - formed from a frequency distribution, 213

improper, 96, 222–227, 231, 250  
 mandatory in Bayesian analyses, 207, 239  
 matching, 229, 230, 235  
 reference, 233  
 unable to correctly represent ignorance, 228  
 with delta function, 252

probability  
 actual vs nominal figure, 50  
 as a term, 219, 243  
 as degree of belief, 34, 209  
 as long-run concept, 34, 56  
 as requiring an event or hypothesis, 5  
 Bayesian concept of, 32, 207  
 conditional, 78, 79  
 controversy about, xii  
 definition of, 34–36, 38  
 fiducial, 205  
 for prediction instead of estimation, 6  
 frequentist and Bayesian scopes of, 36–38, 209–210  
 frequentist concept of, 32, 35, 38  
 in classical statistics, 21  
 lack of definition of, 234  
 legitimate subjects of, 32, 36–38  
 long-run implication of, 34, 86  
 personal/subjective, 34, 210, 260  
 posterior, 209, 224, 225, 234, 252  
 potential presupposition about, 235–236  
 practical implication of, 46, 47  
 practical meaning required for, 32  
 prior, 51, 52, 213, 222, 223  
 requires a long-run context, 124  
 statement, example of, 5  
 vs belief, 38

probability density function, notation, 42  
 probability interval, 215  
 product testing, 164–169, 253

quantile, definition of, 45  
 quantity, as a term, xvii, 241, 244

random, as a term, 31, 42  
 random variable  
 as a term, 42  
 simple definition of, 39  
 variate as synonym for, 42

rational agent, *see* consistent gambler  
 reasonableness distribution, 217–218  
 reference analysis, 233  
 reference values, 25, 29, 44, 61, 132, 148, 215  
 regression, 21, 22, 186–189,  
 regression function, 186  
 rejection region, 247–250  
 repetition  
 broadening of concept of, 22, 31, 60, 201  
 of the experiment, 60, 201  
 of the measurement, 60, 201

sample, as a term, 24  
 significance level, 167, 195, 203  
 adjustment for simultaneous inference, 195  
 significance test, 167  
 simulation of the measurement, 13, 50, 53–55, 74–76, 94, 138–151, 181–183, 262, 263  
 simultaneous inference, 175, 179–184, 187, 195  
 Sleeping Beauty paradox, 64, 260  
 source-coding theorem, 231  
 standardized distribution, 107  
 success rate, 17, 35, 47, 60, 170, 210, 240, 243, 257  
 perception of, 63–65, 71, 76, 86  
 practical, 62, 73, 77, 112, 234  
 success, definition of, xiv, 17, 19, 86, 175

target value  
 definition of, 6, 19  
 measurement without concept of, 6, 214–219  
 uncertainty without concept of, 10, 214–219

Taylor's series, 27, 98, 125, 135  
 time-scale, 28–30, 169–171  
 tolerance interval, 216–217  
 transfer of uncertainty information, 14, 150  
 true value, xii, 4–7, 17, 37, 214  
 uncertainty without concept of, 10  
 Type I error probability, partitioning of, 148

uncertainty (of measurement)  
 as 'experimental uncertainty', 256  
 as a term, 57, 214, 219, 237, 255–257  
 as being specific to observer, 65  
 as potential magnitude of error, 8, 86  
 dependent on purpose, 152–171, 187, 255  
 information about, 14, 118, 150, 152–171  
 interval, meaning of, 16–19, 35, 86, 244  
 language about, 10  
 non-uniqueness of, 15, 124, 256  
 problematic nature of, xii  
 propagation of, 57, 101, 130, 157, 237  
 standard, 8–12, 58, 130, 169–170, 215, 243, 257  
 Type A evaluation of, 29, 124, 239, 240, 243  
 Type B evaluation of, 29, 93, 239–241, 243–244  
 without concept of target value, 10, 214–219

validity, statistical, 15, 48, 96, 140, 149, 175, 184  
 value, as a term, xvii, 219, 244  
 variate  
 as synonym for random variable, 42  
 categorical, 231, 232  
 continuous numerical, 42, 232, 233  
 discrete numerical, 232

weak law of large numbers, 35, 259  
 Welch–Satterthwaite formula, 93  
 Working Group (on the statement of uncertainties), 57–59, 62, 65, 70, 86, 166, 237, 240, 242, 243  
 worst-case values, xii, 56, 60, 69, 70, 72, 166, 169, 204