

# Index

- Additive rules of probability,  
174–177, 181  
  general, 177, 181  
  mutually exclusive events,  
  176, 181
- Alpha (level of significance), 367  
Alpha (probability of type I error), 367  
Alpha (population constant in least-squares line), 503
- Alternate hypothesis  $H_1$ , 361  
  for difference of two means (paired difference), 418  
  for difference of two means (independent samples), 431  
  for difference of two proportions, 450  
  for left-tailed tests, 362, 379  
  for right-tailed tests, 362, 379  
  for test of correlation coefficient, 135–136, 503–504  
  for test of goodness of fit, 484  
  for test of independence, 471  
  for test of mean, 363  
  for test of proportion, 394  
  for test of slope of least-squares line, 508  
  for test of variance, 497  
  for two-tailed tests, 362, 379
- And ( $A$  and  $B$ ), 169–170, 172, 175, 181. *See also* Probability
- Arithmetic mean, 77, 96, 281. *See also* Mean
- Averages, 74–80, 96  
  mean, 77, 96, 210–211, 232–233, 259  
  median, 75, 98  
  mode, 74  
  population mean  $\mu$ , 77, 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 316, 327, 333, 376, 378, 432, 436  
  sample mean  $\bar{x}$ , 77, 96, 125, 210, 281, 316, 331  
  trimmed mean, 78  
  weighted, 79
- $b$  (slope of least-squares line), 137–138, 141, 503, 508
- Back-to-back stem plot, 64  
Bar graph, 48–49, 53  
Benford's Law, 359–360  
Bernoulli, 216
- Bernoulli experiment, 216–217  
Best-fitting line, 136–138. *See also* Least-squares line  
Beta (probability of a type II error), 367  
Beta (population coefficient of least-squares equation), 503, 508
- Bias, 23  
Bimodal histogram, 42  
Binomial, 216–217, 230–233, 296  
  approximated by normal, 296  
  coefficients, 220  
  distribution, 218–220, 230–233, 296  
  experiment, 216–217  
  formula for probabilities, 220  
  histogram, 230  
  mean of binomial distribution, 232–233  
  standard deviation of binomial distribution, 232–233  
  variable ( $r$ ), 217, 296, 339, 394, 449
- Bootstrap, 334  
Boundaries, class, 37, 38  
Box-and-whisker plot, 103
- CV (coefficient of variation), 90  
Categorical data, 5  
Cause-and-effect relations, 130–131  
Cells, 472  
Census, 19  
Central Limit Theorem, 288–291  
Chebyshev's Theorem, 91–92  
Chi-square ( $\chi^2$ ), 470–471, 476–477, 485, 494–495  
  calculation of, 474, 477, 484, 487, 494, 497  
  degrees of freedom for goodness-of-fit test, 486, 487  
  degrees of freedom for independence test, 475, 477  
  degrees of freedom for test of a variance, 494, 497  
  distribution of, 470–471, 494–495  
  test for goodness of fit, 484–487  
  test for independence, 471–477  
  test for a single variance or standard deviation, 494–497
- Circle graph, 50–51, 53  
Class, 34, 35  
  boundaries, 37  
  frequency, 36  
  limits, 35  
  mark, 36  
  midpoint, 36  
  width, 35
- Cluster sample, 15, 16  
Coefficient, binomial, 220  
Coefficient of determination,  $r^2$ , 145  
Coefficient of linear correlation,  $r$ , 123–126  
  formula for, 125, 126  
  testing rho ( $\rho$ ), 135–136, 503–504
- Coefficient of variation, CV, 90  
Combinations rule, 193, 220  
Complement of event  $A$ , 164–165, 181  
Conclusions (for hypothesis testing), 371  
  using critical regions, 387  
  using  $P$ -values, 368–369
- Conditional probability, 170  
Confidence interval, 319, 321  
  for difference of means, 430–432, 434, 435–436, 441  
  for difference of proportions, 454  
  for mean, 316–319, 320–321, 331, 333  
  for predicted value of response variable, 512  
  for proportion, 341
- Confidence level,  $c$ , 316–318  
Confidence prediction band, 514–515  
Confounding variable, 22  
Contingency tables, 179, 472  
Continuity correction for normal approximation to binomial, 299  
Continuous random variable, 207  
Control group, 21, 22  
Convenience sample, 16
- Correlation  
  Pearson product moment correlation coefficient  $r$ , 123–126  
  formula for, 125, 126  
  interpretation of, 127  
  testing rho ( $\rho$ ), 135–136, 503–504
- Criterion for least-squares equation, 137  
Critical regions, 383–384, 387  
Critical values, 317, 329, 383  
  for Chi-square distribution, 470  
  for correlation coefficient,  $r$ , 135–136  
  for normal distribution, 317–318, 383–384, 398, 432, 454  
  for  $t$ , 329, 393, 436

- Data  
 continuous, 207  
 discrete, 206  
 paired (dependent samples),  
 416–417, 429–430  
 population, 5  
 sample, 5  
 qualitative, 5  
 quantitative, 5
- Decision errors, types of, 366–368
- Degrees of freedom (*d.f.*)  
 for chi-square goodness-of-fit test,  
 486, 487  
 for chi-square test of independence,  
 475, 477  
 for chi-square test of variance,  
 494, 497  
 for Student's *t* distribution, confi-  
 dence interval for  
 difference of means, 432, 436,  
 441–448  
 mean, 331, 333  
 prediction, 512  
 for Student's *t* distribution, test of  
 correlation coefficient, 503, 504  
 difference of means, 432, 436,  
 441, 447, 448  
 mean, 379  
 paired difference, 418  
 slope, 508
- Deming, W.E., 49
- de Moivre, 248
- Density function, 250
- Dependent events, 169–170
- Descriptive statistics, 9
- Deviation  
 population standard,  $\sigma$ , 88,  
 210–211, 232–233, 249, 259,  
 281, 286, 289, 296, 319, 327,  
 376, 432, 494, 497  
 sample standard,  $s$ , 83–85, 96, 281,  
 327, 331, 379, 436, 494, 497  
 computation formula, 85, 96
- Difference  
 between two means, 430–432,  
 435–436, 441  
 between two proportions,  
 449–450, 454  
 paired difference test, 417–419
- Discrete random variable, 206
- Disjoint events. *See* Mutually exclusive  
 events
- Distribution  
 bell-shaped, 249  
 bimodal, 42  
 binomial, 220, 230–233, 296  
 chi-square, 470–471, 476–477,  
 494–495  
 normal, 248–250  
 probability, 208, 210–211  
 sampling, 281, 284, 286, 288–291  
 skewed, 42  
 Student's *t*, 328–330, 379, 418, 436,  
 447, 448, 503–504, 508, 512  
 symmetrical, 42, 249  
 uniform, 42
- Dotplot, 47
- Double blind experiment, 22
- E*, maximal margin of error, 318, 323,  
 330, 340, 344, 346, 432, 436  
 for least-squares prediction, 512  
 for difference of proportions, 454  
 for difference of means, independent  
 samples, 432, 436  
 for mean, 318, 330  
 for proportion, 340, 344
- EDA, 56–57, 103
- Empirical rule, 250–251
- Equally likely outcomes, 160–161
- Equation of least-squares line, 137–138
- Error of estimate. *See* Margin of error
- Errors  
 type I, 366–368  
 type II, 366–368
- Estimation, 316–317  
 difference of means, 430–432, 434,  
 435–436, 441  
 difference of proportions, 454  
 mean, 316–321, 330–331, 333  
 predicted value in linear  
 regression, 512  
 proportion, 340–341
- Event, probability of, 160
- Event, 162, 165  
 complement of, 164–165, 181  
 dependent, 169–170  
 equally likely, 160–161  
 failure *F*, binomial, 217  
 independent, 169–170, 181  
 mutually exclusive, 176, 181  
 simple, 162, 165  
 success *S*, binomial, 217
- Expected frequency  
 for contingency table, 472–473, 477  
 for goodness of fit, 484–485, 487
- Expected value, 211  
 for binomial distribution, 232–233  
 for general discrete probability  
 distribution, 211
- Experiment  
 binomial, 216–217  
 double-blind, 22  
 randomized two-treatment, 21  
 statistical, 20, 162, 165
- Experimental design, 19–22
- Explanatory variable in simple regression,  
 120, 131
- Exploratory data analysis, 56–57, 103
- Extrapolation, 141, 514
- F*, failure on a binomial trial, 217.  
*See also* Binomial
- Factorial, 191
- Fail to reject null hypothesis, 371
- Five-number summary, 103
- Frequency, 36  
 expected, 472–473, 477,  
 484–485, 487  
 relative, 37, 160
- Frequency distribution, 38–42. *See also*  
 Histogram
- Frequency histogram, 38–42. *See also*  
 Histogram
- Frequency table, 34–37
- Gauss, C.F., 248
- Gaussian distribution. *See* Normal  
 distribution
- General probability rule  
 for addition, 177, 181  
 for multiplication, 170, 181
- Goodness-of-fit test, 484–487
- Gosset, W.S., 328
- Graphs  
 bar, 48–49, 53  
 circle, 50–51, 53  
 dotplot, 47  
 frequency histogram, 38–42  
 histogram, 38–42  
 Pareto chart, 49, 53  
 relative frequency histogram, 38–41  
 residual plot, 149–150  
 scatter diagram, 120, 154  
 stem-and-leaf display, 57–59  
 time series graph, 52, 53
- Hinge, 104. *See also* Quartile
- Histogram, 38–42  
 bimodal, 42  
 frequency, 38–42  
 how to construct, 38–42  
 relative frequency, 38–42  
 skewed, 42  
 symmetric, 42  
 uniform, 42
- Hypothesis tests, in general, 360–363,  
 365–369  
 alternate hypothesis,  $H_1$ , 361  
 conclusion, 371  
 conclusion based on critical  
 regions, 387

- conclusion based on  $P$ -value, 368–369  
 critical region, 383–384  
 critical value, 383  
 level of significance, 367  
 null hypothesis,  $H_0$ , 361  
 $P$ -value, 365  
 Power of a test, 367
- Hypothesis testing (types of tests)  
 of correlation coefficient, 135–136, 503–504, 509  
 of difference of means, 430–432, 435–436, 441  
 of difference of proportions, 449–450  
 of goodness of fit, 484–487  
 of independence, 471–477  
 of mean, 376–377, 378–379, 383–385  
 of paired differences, 417–419  
 of proportion, 394–395  
 of variance or standard deviation, 494–497
- Independence test, 471–477  
 Independent events, 169–170, 181  
 Independent samples, 429  
 Independent trials, 217  
 Individual, 5  
 Inference, statistical, 9  
 Influential point, 154  
 Interpolation, 141  
 Interquartile range, 100–101  
 Interval, confidence, 316–321, 330–331, 333, 340–341, 430–432, 435–436, 441, 454, 512  
 Interval level of measurement, 7, 8  
 Inverse normal distribution, 272
- Large samples, 289, 296, 339  
 Law of large numbers, 162  
 Leaf, 58, 59  
 Least-squares criterion, 137  
 Least-squares line  
   formula for, 137–138  
   predictions, 141–142, 512  
   slope, 137, 138, 141, 508, 509  
 Level of confidence,  $c$ , 316–318  
 Level of significance, 367  
 Levels of measurement, 6–8, 79  
   interval, 7, 8  
   nominal, 7  
   ordinal, 7, 8  
   ratio, 7, 8  
 Likert scale, 23  
 Limits, class, 35, 38
- Linear regression, 136–141  
 Lower class limit, 35, 38  
 Lurking variable, 22, 23, 130, 131
- Margin of error, 316, 344, 355  
 Marginal change, 141  
 Maximal error of estimate. *See E*, maximal margin of error  
 Mean. *See also* Estimation and Hypothesis testing  
   for binomial distribution, 232–233  
   comparison with median, 78  
   defined, 77  
   discrete probability distribution, 210–211  
   formula for grouped data, 96  
   formula for ungrouped data, 77  
   population, 77, 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 316, 327, 333, 376, 378, 432, 436  
   sample, 77, 96, 125, 210, 281, 316, 331  
   trimmed, 78  
   weighted, 79  
 Median, 75, 98  
 Midpoint, class, 36  
 Mode, 74  
 Mu ( $\mu$ ), population mean, 77, 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 316, 327, 333, 376, 378, 432, 436  
 Multiplication rule of counting, 187  
 Multiplication rule of probability, 170, 172, 181  
   for dependent events, 170, 172, 181  
   for independent events, 170, 172, 181  
 Mutually exclusive events, 176, 181
- $N$ , population size, 77  
 Negative correlation, 124–125  
 Nightingale, Florence, 32, 214  
 Nonresponse, 23  
 Nominal level of measurement, 7, 8  
 Normal approximation to  
   binomial, 296  
 Normal distribution, 248–250, 259, 286, 288–291, 296  
   areas under normal curve, 259–261, 269  
   normal curves, 248–250  
   standard normal, 259  
 Null hypothesis,  $H_0$ , 361, 362. *See also* Alternate hypothesis,  $H_1$   
 Number of degrees of freedom. *See* Degrees of freedom ( $d.f.$ )
- Observational study, 20  
 Observed frequency ( $O$ ), 473, 484  
 Or ( $A$  or  $B$ ), 174, 175  
 Ordinal level of measurement, 7–8  
 Outlier, 105, 108
- $p$  (probability of success in a binomial trial), 217, 281, 339, 394  
 $\hat{p}$ , point estimate of  $p$ , 241, 281, 340, 394, 449, 454  
 $\bar{p}$ , pooled estimate of a proportion, 450  
 $P$ -value, 365, 369  
 Paired data, 416–417  
 Paired difference test, 417–419  
 Parameter, 280–281, 316, 363  
 Pareto chart, 49, 53  
 Pearson, Karl, 124  
 Pearson product moment correlation coefficient  $r$ , 123–126  
 Percentile, 98–100  
 Permutations rule, 192  
 Pie chart, 50–51, 53  
 Placebo, 21  
 Point estimate  
   for population mean, 316  
   for population proportion, 340  
   for population probability of success, 340  
 Pooled estimate  
   of a proportion,  $\bar{p}$ , 450  
   of a standard deviation,  $s$ , 441, 448  
   of a variance,  $s^2$ , 418  
 Population  
   defined, 5, 280  
   mean  $\mu$ , 77, 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 316, 327, 333, 376, 378, 432, 436  
   standard deviation  $\sigma$ , 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 319, 327, 376, 432, 494, 497  
 Population parameter, 280–281, 503  
 Positive correlation, 124–125  
 Power of a test, 367  
 Prediction for  $y$  given  $x$ , 141–142  
 Probability  
   addition rule (general events), 177, 181  
   addition rule (mutually exclusive events), 176, 181  
   binomial, 220  
   of the complement of an event, 164–165, 181  
   conditional, 170  
   defined, 160, 165  
   of an event, 160  
   multiplication rule (general events), 170, 172, 181

- multiplication rule (independent events), 170, 172, 181
- Probability distribution, 41, 208–211
  - continuous, 206
  - discrete, 206, 230
  - mean, 210–211
  - standard deviation, 210–211
- Proportion, estimate of  $\hat{p}$ , 281, 340
- Proportion, pooled estimate  $\bar{p}$ , 450
- Proportion, test of, 394–395
  
- $q$ , probability of failure in a binomial trial, 217
- Qualitative variable, 5
- Quantitative variable, 5
- Quartile, 100
  
- $r$ , number of successes in a binomial experiment, 217, 296, 339, 394, 450, 454
- $r$ , Pearson product moment correlation coefficient, 123–126
- $r^2$ , coefficient of determination, 145–146
- Random, 12–13
- Random number generator, 15, 30–31
- Random number table, 13
- Random sample, 12–13
- Random variable, 206
- Randomized two-treatment experiment, 21
- Range, 83
- Ratio level of measurement, 7, 8
- Raw score, 258
- Region, rejection or critical, 383–384
- Regression, linear, 136–138
- Reject null hypothesis, 371
- Rejection region. *See* Critical region
- Relative frequency, 37, 160
- Relative frequency table, 37, 38
- Replication, 22
- Residual, 149, 505
- Residual plot, 149–150
- Resistant measures, 78
- Response variable in regression, 120, 131
- Rho ( $\rho$ ), 130, 135–136, 503, 504
  
- $s$ , pooled standard deviation, 441, 448
- $s$ , sample standard deviation, 83–85, 96, 281, 327, 331, 379, 494, 497
- $s^2$ , sample variance, 83, 84, 85, 494, 497
- $S$ , success on a binomial trial, 217
  
- Sample, 5
  - cluster, 15, 16
  - convenience, 15, 16
  - large, 289, 296, 339
  - mean, 77, 96, 232–233, 281, 316, 331
  - simple random, 12
  - standard deviation  $s$ , 83–85, 96, 281, 327, 331, 379, 494, 497
  - stratified, 15, 16
  - systematic, 15, 16
  - variance  $s^2$ , 83, 84, 85, 494, 497
  - voluntary response, 23
- Sample size, determination of, for estimating a mean, 322–323
  - for estimating a proportion, 346–347
- Samples
  - independent, 429
  - repeated with replacement, 15, 30, 217
  - repeated without replacement, 15, 30, 217
- Sample space, 162, 165
- Sample test statistic. *See* Test statistic
- Sampling, 11–16
  - cluster, 15, 16
  - convenience, 15, 16
  - simple random, 12
  - stratified, 15, 16
  - systematic, 15, 16
  - with replacement, 15, 30, 217
- Sampling distribution. *See also* Central Limit Theorem
  - for proportion, 340
  - for mean, 280–289
- Satterthwaite's formula for degrees of freedom, 436, 448
- Scatter diagram, 120
- Sigma
  - $\sigma$ , 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 319, 327, 376, 432, 494, 497
  - $\Sigma$ , 77
- Significance level, 367
- Simple event, 162, 165
- Simple random sample, 12
- Simulation, 14, 20
- Skewed distribution, 42
- Slope of least-squares line, 137–138, 141, 503, 508
- Standard deviation
  - for binomial distribution, 233
  - pooled, 450
  - for population standard  $\sigma$ , 88, 210–211, 232–233, 249, 259, 281, 286, 289, 296, 319, 327, 376, 432, 494, 497
  - for sample standard  $s$ , 83–85, 96, 281, 327, 331, 379, 436, 494, 497
- for distribution of sample proportion, 340
- for distribution of sample mean, 286, 288, 288–291
- for testing a variance, 494–497
- Standard error
  - of mean, 288
  - of proportion, 340
  - of slope, 508
- Standard error of estimate,  $S_e$ , 506
- Standard normal distribution, 259
- Standard score,  $z$ , 256–257
- Standard unit,  $z$ , 256–257
- Statistic, 280–281, 503
- Statistical experiment, 20, 162, 165
- Statistical significance, 369
- Statistics
  - definition, 5
  - descriptive, 9
  - inferential, 9
- Stem, 58, 59, 62
- Stem-and-leaf display, 57–59
  - back-to-back, 64
  - split stem, 62
- Strata, 15
- Stratified sampling, 15, 16
- Student's  $t$  distribution, 328–330, 379, 418, 435, 436, 447, 448, 503–504, 508, 512
- Sum of squares,  $SS$ , 84
- Summation notation,  $\Sigma$ , 77
- Survey, 23–24
- Symmetrical distribution, 42
- Systematic sampling, 15, 16
  
- $t$  (Student's  $t$  distribution), 328–330, 379, 418, 435, 436, 447, 448, 503–504, 508, 512
- Tally, 36
- Tally survey, 179
- Test for independence, 471–477
- Test of hypotheses. *See* Hypothesis testing
- Test statistic, 363
  - for chi-square goodness-of-fit test, 484, 487
  - for chi-square test of independence, 474, 477
  - for chi-square test of variance, 494, 497
  - for correlation coefficient, rho ( $\rho$ ), 503, 504, 509
  - for difference of means
    - dependent samples, 418, 419
    - independent samples, 432, 436, 441
  - for difference of proportions, 450
  - for mean, 363, 377, 379

- for proportion, 395
- for slope of least-squares line, 508, 509
- Time series, 53
- Time series graph, 52, 53
- Tree, 188
- Trial, binomial, 216–217
- Trimmed mean, 78
- Two-tailed test, 362–363
- Type I error, 366–368
- Type II error, 366–368
  
- Uniform distribution, 42
- Upper class limit, 35
  
- Variable, 5
  - continuous, 207
  - discrete, 206
  - explanatory, 120, 131
  - qualitative, 5
  - quantitative, 5
  - random, 206
  - response, 120, 131
  - standard normal, 259. *See also*  $z$  value
- Variance, 83
  - estimate of pooled, 440–441, 448
  - for ungrouped sample data,  $s^2$ , 83, 84, 85
  - population, 88, 494, 497
  - sample,  $s^2$ , 83, 84, 85, 494, 497
  - testing, 494–497
  
- Variation
  - explained, 145
  - unexplained, 145
- Voluntary response sample, 23
  
- Welch approximation, 435
- Weighted average, 79
- Whisker, 103
  
- $\bar{x}$  (x bar), 77, 96, 125, 210, 281, 331, 316. *See also* Mean
- $z$  score, 256–257, 286, 291
- $z$  value, 256–257, 286, 291