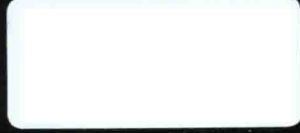


# STATISTICS

for Engineering and the Sciences



**SIXTH EDITION**



William M. Mendenhall ■ Terry L. Sincich



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SIXTH EDITION

# STATISTICS

for Engineering and the Sciences

William M. Mendenhall ■ Terry L. Sincich

**Statistics for Engineering and the Sciences, Sixth Edition** is designed for a two-semester introductory course on statistics for students majoring in engineering or any of the physical sciences. This popular text continues to teach you the basic concepts of data description and statistical inference as well as the statistical methods necessary for real-world applications. You will understand how to collect and analyze data and think critically about the results.

## New to the Sixth Edition

- Many new and updated exercises based on contemporary engineering and scientific-related studies and real data
- More statistical software printouts and corresponding instructions for use that reflect the latest versions of the SAS, SPSS, and MINITAB software
- Introduction of the case studies at the beginning of each chapter
- Streamlined material on all basic sampling concepts, such as random sampling and sample survey designs, which gives you an earlier introduction to key sampling issues
- New examples on comparing matched pairs versus independent samples, selecting the sample size for a designed experiment, and analyzing a two-factor experiment with quantitative factors
- New section on using regression residuals to check the assumptions required in a simple linear regression analysis

The first several chapters of the book identify the objectives of statistics, explain how to describe data, and present the basic concepts of probability. The text then introduces the two methods for making inferences about population parameters: estimation with confidence intervals and hypothesis testing. The remaining chapters extend these concepts to cover other topics useful in analyzing engineering and scientific data, including the analysis of categorical data, regression analysis, model building, analysis of variance for designed experiments, nonparametric statistics, statistical quality control, and product and system reliability.



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Mendenhall  
Sincich



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# **STATISTICS**

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**SIXTH EDITION**





# Preface

## Overview

This text is designed for a two-semester introductory course in statistics for students majoring in engineering or any of the physical sciences. Inevitably, once these student graduate and are employed, they will be involved in the collection and analysis of data and will be required to think critically about the results. Consequently, they need to acquire knowledge of the basic concepts of data description and statistical inference and familiarity with statistical methods that will be required use on the job.

## Pedagogy


Chapters 1 through 6 identify the objectives of statistics, explain how we can describe data, and present the basic concepts of probability. Chapters 7 and 8 introduce the two methods for making inferences about population parameters: estimation with confidence intervals and hypothesis testing. These notions are extended in the remaining chapters to cover other topics that are useful in analyzing engineering and scientific data, including the analysis of categorical data (Chapter 9), regression analysis and model building (Chapters 10–12), the analysis of variance for designed experiments (Chapters 13–14), nonparametric statistics ((Chapter 15), statistical quality control (Chapter 16), and product and system reliability (Chapter 17).

## Features

Hallmark features of this text are as follows:

1. **Blend of theory and applications.** The basic theoretical concepts of mathematical statistics are integrated with a two-semester presentation of statistical methodology. Thus, the instructor has the option of presenting a course with either of two characteristics—a course stressing basic concepts and applied statistics, or a course that, while still tilted toward application, presents a modest introduction to the theory underlying statistical inference.
2. **Statistical software applications with tutorials.** The instructor and student have the option of using statistical software to perform the statistical calculations required. Output from three popular statistical software products — SAS, SPSS, and MINITAB—as well as Microsoft Excel are fully integrated into the text. Tutorials with menu screens and dialog boxes associated with the software are provided in Appendices C, D, and E. These tutorials are designed for the novice user; no prior experience with the software is needed.
3. **Blended coverage of topics and applications.** To meet the diverse needs of future engineers and scientists, the text provides coverage of a wide range of data analysis topics. The material on multiple regression and model building (Chapters 11–12), principles of experimental design (Chapter 13), quality control (Chapter 15), and reliability (Chapter 17) sets the text apart from the typical introductory statistics text. Although the material often refers to theoretical concepts, the presentation is oriented toward applications.
4. **Real data-based examples and exercises.** The text contains large number of applied examples and exercises designed to motivate students and suggest future uses of the methodology. Nearly every exercise and example is based on data or experimental results from actual engineering and scientific studies published in academic journals or obtained from the organization conducting the analysis. These applied exercises are located at the end of every section and at the ends of chapters.



5. **Statistics in Action case studies.** Each chapter begins with a discussion of an actual contemporary scientific study (“Statistics in Action”) and the accompanying data. The analysis and inferences derived from the study are presented at key points in the chapter (“Statistics in Action Revisited”). Our goal is to show the students the importance of applying sound statistical methods in order to evaluate the findings and to think through the statistical issues involved.
6. **End-of-chapter summary material.** At the end of each chapter, we provide a summary of the topics presented via a “Quick Review” (key words and key formulas), “Language Lab” (a listing of key symbols and pronunciation guide), and “Chapter Summary Notes/Guidelines”. These features help the student summarize and reinforce the important points from the chapter and are useful study tools.
7. **Standard mathematical notation for a random variable.** Throughout the chapters on random variables, we use standard mathematical notation for representing a random variable. Uppercase letters represent the random variable, and lowercase letters represent the values that the random variable can assume.
8. **Bootstrapping and Bayesian methods.** In optional sections, the text presents two alternative estimation methods (Section 7.12) and hypothesis testing methods (Section 8.13) that are becoming more popular in scientific studies—bootstrapping and Bayesian methods.
9. **All data sets provided online.** All of the data associated with examples, exercises, and Statistics in Action cases are made available online at [www.crcpress.com/product/isbn/9781498728850](http://www.crcpress.com/product/isbn/9781498728850). Each data file is marked with a  icon and file name in the text. The data files are saved in four different formats: MINITAB, SAS, SPSS, and Excel. By analyzing these data using statistical software, calculations are minimized, allowing student to concentrate on the interpretation of the results.

## New to the Sixth Edition

Although the scope and coverage remain the same, the 6th edition of the text contains several substantial changes, additions, and enhancements:

1. **Over 1,000 exercises, with revisions and updates to 30%.** Many new and updated exercises, based on contemporary engineering and scientific-related studies and real data, have been added. Most of these exercises—extracted from scientific journals—foster and promote critical thinking skills.
2. **Updated technology.** Throughout the text, we have increased the number of statistical software printouts. All printouts from statistical software (SAS, SPSS, and MINITAB) and corresponding instructions for use have been revised to reflect the latest versions of the software.
3. **Statistics in Action Revisited.** For this edition, we introduce the “Statistics in Action” case (see above) at the beginning of each chapter. After covering the required methodology in the chapter, the solution (data analysis and inference) is then presented and discussed in a “Statistics in Action Revisited” at the end of the section.
4. **Chapter 1 (Collecting Data/Sampling).** Material on all basic sampling concepts (e.g., random sampling and sample survey designs) has been streamlined and moved to Section 1.4 to give the students an earlier introduction to key sampling issues.

5. **Chapter 7 (Matched Pairs vs. Independent Samples).** We have added an example (Example 7.12) that compares directly the analysis of data from matched pairs with a similar analysis of the data using an independent samples  $t$ -test.
6. **Chapter 8 (Hypothesis Test/ $p$ -values).** The section on  $p$ -values in hypothesis testing (Section 8.5) has been moved up to emphasize the importance of their use in engineering and scientific-related studies. Throughout the remainder of the text, conclusions from a test of hypothesis are based on  $p$ -values.
7. **Chapters 10 and 11 (Regression Residuals).** A new section (Section 10.8) has been added on using regression residuals to check the assumptions required in a simple linear regression analysis. A similar section (Section 11.10) in the multiple regression chapter has been modified to emphasize the different uses of regression residuals, including for assumption verification and for detecting outliers and influential observations.
8. **Chapter 13 (Experimental Design).** Two new examples (Examples 13.6 and 13.7) have been added on selecting the sample size for a designed experiment.
9. **Chapter 14 (Analysis of Variance).** Two new examples (Examples 14.8 and 14.10) have been added on analyzing a two-factor experiment with quantitative factors. The first employs the traditional ANOVA model and the second utilizes a regression model with higher-order terms.

Numerous, less obvious changes in details have been made throughout the text in response to suggestions by current users and reviewers of the text.

## Supplements

### ***Student Solutions Manual***

Includes complete worked out solutions to the odd-numbered text exercises.

### ***Instructor's Solutions Manual***

Solutions to all of the even-numbered text exercises are given in this manual. Careful attention has been paid to ensure that all methods of solution and notation are consistent with those used in the core text.

## Acknowledgments

This book reflects the efforts of a great many people over a number of years. First, we would like to thank the following professors, whose reviews and comments on this and prior editions have contributed to the 6th edition:

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