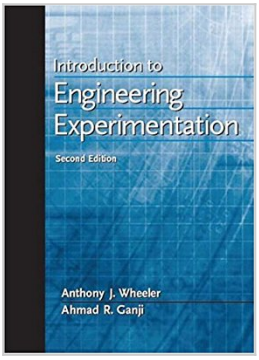


# Introduction to Engineering Experimentation (2nd Edition)

*By Anthony J. Wheeler, Ahmad R. Ganji*



**Introduction to Engineering Experimentation (2nd Edition)** By Anthony J. Wheeler, Ahmad R. Ganji

Appropriate for undergraduate-level courses in Introduction to Engineering Experimentation found in departments of Mechanical, Aeronautical, Civil, and Electrical Engineering. Wheeler and Ganji introduce many topics that engineers need to master in order to plan, design and document a successful experiment or measurement system. The text offers thorough discussions of topics often ignored or merely touched upon by other texts, including modern computerized data acquisition systems, electrical output measuring devices, and in-depth coverage of experimental uncertainty analysis.

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**Introduction to Engineering Experimentation (2nd Edition) By Anthony J. Wheeler, Ahmad R. Ganji Bibliography**

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## Editorial Review

From the Publisher
Wheeler and Ganji introduce many topics that engineers need to master in order to plan, design and document a successful experiment or measurement system. The text offers thorough discussions of topics often ignored or merely touched upon by other texts, including modern computerized data acquisition systems, electrical output measuring devices, and in-depth coverage of experimental uncertainty analysis.

From the Back Cover

Based on the authors' industrial and academic experience, this book has been developed for an undergraduate course in engineering experimentation at the junior or senior level. The book can also be a useful reference for practicing engineers. The material covers the most common elements necessary to design, execute, analyze, and document an engineering experiment or to specify instrumentation for a production process.

**Key Features of the Book**

- Introduction of the common nomenclature for measuring devices and presentation of the standard method to calibrate instruments
- Characteristics of signal conditioners, including amplifiers and filters
- Description of computerized data acquisition systems
- Detailed discussion of the sampling rate theorem and signal analysis using Fourier series and Fourier transforms
- Detailed coverage of the most common statistical techniques and probability distributions
- Detailed coverage of the most recent standard for uncertainty analysis
- Descriptions of the most common engineering measuring devices
- Detailed coverage of the dynamic characteristics of measuring systems with practical applications
- Common techniques for planning and documenting experiments
- Extensive end-of-chapter problems based on realistic industrial practice

In addition to descriptions of common instruments, the book also includes common statistical techniques, data acquisition systems, and aspects of discrete sampling.



This book is an introduction to many of the topics that an engineer needs to master in order to successfully design experiments and measurement systems. In addition to descriptions of common measurement systems, the book describes computerized data acquisition systems, common statistical techniques, experimental uncertainty analysis, and guidelines for planning and documenting experiments. It should be noted that this book is introductory in nature. Many of the subjects covered in a chapter or a few pages here are the subjects of complete books or major technical papers. Only the most common measurement systems are included—there exist many others that are used in practice. More comprehensive studies of available literature and consultation with product vendors are appropriate when engaging in a significant real-world experimental program. It is to be expected that the skills of the experimenter will be enhanced by more advanced courses in experimental and measurement systems design and practical experience.

The design of an experimental or measurement system is inherently an interdisciplinary activity. For example, the instrumentation and control system of a process plant might require the skills of chemical engineers, mechanical engineers, electrical engineers, and computer engineers. Similarly, the specification of the instrumentation used to measure the earthquake response of a large structure will involve the skills of civil, electrical, and computer engineers. Based on these facts, the topics presented in this book have been selected to prepare engineering students and practicing engineers of different disciplines to design experimental projects and measurement systems.

This book was conceived when a decision was made at San Francisco State University to upgrade the laboratory of our first experimental course from using primarily mechanical instruments to using electrical output devices, and to introduce the students to the acquisition and processing of the data with computer systems. The lecture was upgraded at the same time to include the new topics. A survey was made of available texts, and none was found to provide complete coverage of the material in the revised course. The primary deficiencies were in the coverage of computerized data acquisition systems, statistics, and the design and documentation of experiments. Consequently, we created a course reader, which was subsequently expanded to become this book.

The book first introduces the essential general characteristics of instruments, electrical measurement systems, and computerized data acquisition systems. This introduction gives the students a foundation for the laboratory associated with the course. The theory of discretely sampled systems is introduced next. The book then moves into statistics and experimental uncertainty analysis, which are both considered central to a modern course in experimental methods. It is not anticipated that the remaining chapters will necessarily be covered either in their entirety or in the presented sequence in lectures—the instructor will select appropriate subjects. Descriptions and theory are provided for a wide variety of measurement systems. There is an extensive discussion of dynamic measurement systems with applications. Finally, guidance for planning experiments, including scheduling, cost estimation, and outlines for project proposals and reports, are presented in the last chapter.

There are some subjects included in the introductory chapters that are frequently of interest, but are often not considered vital for an introductory experimental methods course. These subjects include the material on circuits using operational amplifiers (Sections 3.2.2, 3.2.5 and 3.2.6), details on various types of analog-to-digital converters (Section 4.3.3), and the material on Fourier transforms (Section 5.3). Any or all of these sections can be omitted without significant impact on the remainder of the text.

The book has been designed for a semester course of up to three lectures with one laboratory per week. Depending on the time available, it is expected that only selected topics will be covered. The material covered depends on the number of lectures per week, the prior preparation of students in the area of statistics, and the scope of included design project(s). The book can serve as a reference for subsequent laboratory courses.

Our introductory course in engineering experimentation is presented to all undergraduate engineers in civil, electrical, and mechanical engineering. The one-semester format includes two lectures per week and one three-hour laboratory. In our two-lecture-per-week format, the course content is broken down as follows:

1. General aspects of measurement systems (2 lectures)
2. Electrical output measurement systems (2 lectures)
3. Computerized data acquisition systems (3 lectures)
4. Fourier analysis and the sampling rate theorem (4 lectures)
5. Statistical methods and uncertainty analysis (10 lectures)
6. Selected measurement devices (4 lectures)

7. Dynamic measurement systems (3 lectures)

Additional measurement systems and the material on planning and documenting experiments are covered in the laboratory. The laboratory also includes an introduction to computerized data acquisition systems and applicable software; basic measurements such as temperature, pressure, and displacement; statistical analysis of data; the sampling rate theorem; and a modest design project. A subsequent laboratory-only course expands on the introductory course and includes a significant design project.

There is sufficient material for a one-semester, three-lecture-per-week course even if the students have taken a prior course in statistics. Areas that can be covered in greater detail include operational amplifiers, analog-to-digital converters, spectral analysis, uncertainty analysis, measurement devices, dynamic measurements, and experiment design.

In this second edition, Chapter 6 on statistics has been significantly enhanced to include the Poisson distribution, multiple and polynomial regression, outlier analysis for *x*-*y* data sets, and linear functions of random variables. Chapter 7 on uncertainty analysis has been extensively modified to make it compatible with the latest ASME standard and to provide a simpler path through the material for large data samples. Chapter 5 has been modified to include the folding diagram for predicting alias frequencies and to make the nomenclature for Fourier series consistent with common current usage. Numerous lesser alterations have been made throughout the book to clarify, update, or enhance the material. Finally, the number of homework problems has been increased by 50%.

## Users Review

**From reader reviews:**

**Charles Wilkerson:**

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**Angela Heller:**

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