

# Preface

This book is for designers, partition engineers, and student of engineering. It introduces the fundamental knowledge used in *mechanical vibrations*. This knowledge can be utilized to develop computer programs for analyzing, designing, and optimization of vibration problems in industrial systems.

Vibrations have been in the engineering curriculum for around a hundred years. Many good books on the subject are available. The 1896 Lord Rayleigh's "*Theory of Sound*" is the first modern book on the subject of sound, wave propagation, and vibrations. However, the first books on vibrations with a mechanical engineering viewpoint appeared as "*Vibration Problems in Engineering*" (1928) by the father of modern engineering mechanics, Stephen P. Timoshenko, and then as "*Mechanical Vibrations*" (1934) by J.P. Den Hartog. Although Timoshenko was the architect of modern structure of engineering education and his various books were used for a long time in educating mechanical and civil engineers, it was Den Hartog's *Mechanical Vibrations* that globally was accepted as a classical educational book. Almost all mechanical vibration books that appeared after 1940 follow the structure of Den Hartog's, starting with time response and ending with frequency response. Sometimes a glance at random vibrations, nonlinear vibrations, continuous systems, vibrations control, or modal analysis may also be seen in various books. On the contrary, the present book begins with frequency response and continues by time response and ends with optimization and application, focusing only on discrete mechanical systems. Starting with frequency and steady-state response of vibrating systems is more practical and more fundamental than time and transient response.

## Level of the Book

This book has evolved from nearly two decades of research and optimization of vibrating systems and teaching courses in fundamental and advanced vibrations. It is addressed primarily to the last year of an undergraduate study and the first year graduate study in engineering. Hence, it is an intermediate textbook. It provides the

reader with both fundamental and advanced topics. The whole book can be covered in two successive courses; however, it is possible to jump over some sections and cover the book in one course. Students are required to know the fundamentals of kinematics and dynamics, as well as have a basic knowledge of numerical methods.

The contents of the book have been kept at a fairly theoretical-practical level. Many concepts are deeply explained and their application emphasized, and most of the related theories and formal proofs have been explained. The book places a strong emphasis on the physical meaning and applications of the concepts. Topics that have been selected are of high interest in the field. An attempt has been made to expose students to a broad range of topics and approaches.

An asterisk ★ indicates a more advanced subject or example, which is not designed for undergraduate teaching and can be dropped in a first reading.

## Organization of the Book

The text is organized so that it can be used for teaching or for self-study.

Part I, “Vibration Fundamentals,” introduces the vibrations as a cause for the transformation of energy. It covers kinematics of vibrations, and develops practical skills to derive the equations of motion of vibrating systems. The concepts of the Newton–Euler dynamics and Lagrangean method are used equally for derivation of equations of motion.

Part II, “Frequency Response,” covers the methods of developing the steady-state frequency response of vibrating systems to harmonic excitations.

Part III, “Time Response,” covers the time and transient responses of vibrating systems to free or non-harmonic excitations.

Part IV, “Applications,” presents vibration optimization and studies the vibrations of vehicles as the most observable vibrating systems. An attempt is made to review the basic approaches and demonstrate how a vehicle can be modeled as a vibrating multiple degree-of-freedom system. The root mean square optimization technique for suspension design of vehicles is introduced and applied to vehicle suspensions. The outcome of the optimization technique is the optimal stiffness and damping for a car or suspended equipment.

## Method of Presentation

This book uses a “*fact-reason-application*” structure. The “fact” is the main subject we introduce in each section. Then the reason is given as a “proof.” The application of the fact is examined in some “examples.” The “examples” are a very important part of the book. They show how to implement the “facts” and also cover some other facts that are needed to expand the subject.

## **Prerequisites**

Since the book is written for senior undergraduate and first-year graduate-level students of engineering, the assumption is that users are familiar with matrix algebra as well as basic dynamics. Prerequisites are the fundamentals of kinematics, dynamics, and matrix theory. These topics are usually taught in the first three undergraduate years.



<http://www.springer.com/978-1-4614-4159-5>

Advanced Vibrations

A Modern Approach

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2013, XVI, 696 p., Hardcover

ISBN: 978-1-4614-4159-5