

Preface

Objectives of the Book

This book is devoted to the acoustics of musical instruments. Its prime aim is to highlight the physical principles that govern the production and radiation of sound by these complex sources. It is the result of several years of work which would not have been possible without the active and enthusiastic contribution of colleagues to whom we wish to extend our sincere thanks and gratitude. We should also mention that Chap. 10 on the flute was written by Benoît Fabre and Chap. 11 on the violin by Xavier Boutillon. Jean-Pierre Dalmont, Joël Gilbert and Cyril Touzé wrote some paragraphs in the third part.

The book is meant primarily as a textbook for students at master's and doctorate levels. This is the reason why it includes a large number of significant equations where the mathematical derivations are presented in detail. In addition, we thought that it was necessary to account for the most recent results of research in musical acoustics. Therefore, a large number of references can be found at the end of each chapter. N. Fletcher and T. Rossing's famous book *Physics of Musical Instruments* (Springer) was published in 1991, and ever since this field of research has benefitted from plenty of new discoveries. One can cite, for example, the essential contribution of fluid dynamics and aeroacoustics for the comprehension of wind instruments, the interest of nonlinear structural models for describing the behaviour of cymbals and gongs and, more generally, the application of the theory of dynamical systems to every class of instruments.

In fact, this book is intended not only for students but also to researchers, engineers and other physicists with a strong interest in music. We also hope that musicians, instrument makers and music lovers who wish to acquire some basic knowledge on the physics of musical instruments will be able to read it profitably, even if they cannot follow all mathematical aspects in detail. In this view, the links between physical phenomena, instrument making and playing are explained as clearly as possible.

How much remains unknown in the realm of musical instruments? Is it worth putting so much attention to the instrument itself, given the somewhat fundamental role of the player in the subtleties of musical sound? Our belief is that a number of phenomena still remain to be elucidated with regard to the production and radiation of sound in musical instruments, despite the contribution of famous acousticians over the last four centuries. It is remarkably difficult to find the physical basis of musical instruments in a single book, due to the great variety of the subjects involved.

Basically, all musical instruments are governed by fundamental laws of fluid and solid mechanics, including acoustics and vibrations. Today, the main outlines of these laws are well known. However, musical instruments are very subtle sound sources that need to be described with great accuracy, in view of the ability of the players and sensitivity of the human ear. In the case of a violin, for example, the sound results from continuous friction of a bow on a stretched string, one end of which is connected to a bridge attached to the soundboard. In Chap. 11, we will see that even the melding properties of the rosin play an important role in the origin of the oscillations of the string and, in turn, of the violin sound.

Two main aspects must be considered with regard to the perception of a musical instrument. First, we need to understand the causes that influence the perception of the instrument by the player: the so-called playability of the instrument. Second, we want to identify the factors influencing the perception of sound by the listeners, including the player, which can be referred to as “sound quality”. Today, the science has not found an entirely satisfying answer to these questions. In this context, this book attempts to review and to describe the physical phenomena related to these problems. The auditory perception is sometimes mentioned in this book, and this seems to be natural in view of the normal function of an instrument. However, its prime objective is to analyse the instrument and its playing from the point of view of the physics.

Contents of the Book

In the first part “Basic Equations and Oscillators”, the main continuous models of the elementary constitutive parts of the instruments are described: strings, bars, plates, tubes, etc. In addition, models of the excitation mechanisms (finger, mallet, etc.) are presented, which are specific to musical instruments. The single degree of freedom (SDOF) oscillator is presented in detail in the second chapter, since its properties are essential and serve as references for the rest of the book.

The fundamental concepts of sound waves and modes of vibrations are presented in the second part “Waves and Modes”, starting from the simple case of 1-D waves. The concepts are illustrated by examples which are directly linked to musical instruments: plucked string, wind and percussive instruments. Emphasis is put on the equivalences between temporal and modal representations, since the transition from time to modal domain is of high interest in musical acoustics. For pedagogical

Acoustics of Musical Instruments

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2016, XXV, 844 p. 357 illus., 355 illus. in color.,

Hardcover

ISBN: 978-1-4939-3677-9