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# Principles of Musical Acoustics

 Springer

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*To Mitra and Daniel*



# Preface

Musical acoustics is a scientific discipline that attempts to put the entire range of human musical activity under the microscope of science. Because science seeks understanding, the goal of musical acoustics is nothing less than to understand how music “works,” physically and psychologically. Accordingly, musical acoustics is multidisciplinary. At a minimum it requires input from physics, physiology, psychology, and several engineering technologies involved in the creation and reproduction of musical sound.

As a scientific discipline, musical acoustics poses several questions. The first question has to be, “Why would anyone want to study it?” Unlike some other scientific pursuits, it is unlikely to improve the health of the population, nor is it likely to be the engine that drives the economy to new heights. The answer to the question lies within the appeal of music itself. Music is fundamentally important to human beings—it has been a part of every culture throughout history. Nothing has greater capability to inspire human emotions. Thus musical acoustics is an attempt to take a *rational* approach to a human activity that is essentially emotional. In the end, music is compelling. It compels us to listen to it, to create it, and ultimately to try to understand it.

Musical acoustics is an ancient science—the rational approach to music was part of the ancient Greek quadrivium. Musical acoustics also claims an ancient technology. For instance, the greatest violins in history were made in the eighteenth century. Is there any other scientific discipline where the peak of a relevant technology occurred more than 200 years ago? At the same time, musical acoustics is modern. New electronic methods of producing, processing, and recording music appear with every new year. The discipline forms an important part of our rapidly developing worldwide communications technology, and the study of music processing by the human brain is an important aspect of contemporary neuroscience.

The teaching and learning of musical acoustics likewise presents some challenges. As an ancient science, with millions of participants as performers and instrument makers, and a technology that is as much art as it is science, the subject abounds in details. Every musical idea and every musical instrument have seen dozens of variations—some enduring, others fleeting curiosities. These details

are often fascinating, and they are part of the charm of the subject. Musicians are justifiably proud of their rich musical culture. On the other hand, students approaching the subject for the first time can easily be overwhelmed by all the details. As its name implies, this little book, *Principles of Musical Acoustics*, focuses on the basic principles in the science and technology of music. Musical examples and specific musical instruments demonstrate the principles.

This book begins with a study of vibrations and waves—in that order. These topics constitute the basic physical properties of sound, one of two pillars supporting the science of musical acoustics. The second pillar is the human element, the physiological and psychological aspects of acoustical science. The perceptual topics include loudness, pitch, tone color, and localization of sound.

With these two pillars in place, it is possible to go in a variety of directions and in no particular order. The book treats in turn the topics of room acoustics, audio—both analog and digital—broadcasting, and speech. It ends with chapters on the traditional musical instruments, organized by family.

The mathematical level of this book assumes that the reader is familiar with elementary algebra. Trigonometric functions, logarithms, and powers also appear in the book, but computational techniques are included as these concepts are introduced, and there is further technical help in appendices.

There are exercises at the end of each chapter. Most of the exercises follow in a straightforward way from material presented in the chapter. Other exercises are a bit of a stretch. Both kinds are useful. Rather complete answers to most of the exercises appear in the back of the book, but anyone who wants to use this book for serious study ought to try to do the exercises before looking up the answers in the back. The goal, of course, is active involvement with the material in the text. Working an exercise, even if unsuccessfully, is of more value than reading a text passively.

The elements in this book have been developed over the course of several decades in teaching musical acoustics in the Department of Physics and Astronomy at Michigan State University. I am grateful to the thousands of students who have experienced the course and given me inspiration, advice, data, cheers, complaints, and other forms of feedback. Especially, I am particularly grateful to Professor Jon Pumplin, Dr. Diana Ma, and Mr. John McIntyre for helpful suggestions. Tim McCaskey, Nick Nuar, Ben Frey, Louis McLane, and Yun Jin Cho helped me assemble notes into this volume. I could not have written this book without their help. Finally, I am grateful to my wife, Christine Hartmann, for her support over the years.

East Lansing, MI, USA

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