Preface

Acoustics is a most fascinating subject. Music, architecture, engineering, science, drama, medicine, psychology, and linguistics all seek from it answers to basic questions in their field. In the Acoustics Laboratory at M.I.T. students may be found working on such diversified problems as auditorium and studio design, loudspeaker design, subjective perception of complex sounds, production of synthetic speech, propagation of sound in the atmosphere, dispersion of sound in liquids, reduction of noise from jet-aircraft engines, and ultrasonic detection of brain tumors. The annual meetings of the Acoustical Society of America are veritable five-ring shows, with papers and symposia on subjects in all the above-named fields. Opportunities for employment are abundant today because management in industry has recognized the important contributions that acoustics makes both to the improvement of their products and to the betterment of employee working conditions.

There is no easy road to an understanding of present-day acoustics. First the student must acquire the vocabulary that is peculiar to the subject. Then he must assimilate the laws governing sound propagation and
sound radiation, resonance, and the behavior of transducers in an acoustic medium. Last, but certainly not of least importance, he must learn to understand the hearing characteristics of people and the reactions of listeners to sounds and noises.

This book is the outgrowth of a course in acoustics that the author has taught to seniors and to first-year graduate students in electrical engineering and communications physics. The basic wave equation and some of its more interesting solutions are discussed in detail in the first part of the text. The radiation of sound, components of acoustical systems, microphones, loudspeakers, and horns are treated in sufficient detail to allow the serious student to enter into electroacoustical design.

There is an extensive treatment of such important problems as sound in enclosures, methods for noise reduction, hearing, speech intelligibility, and psychoacoustic criteria for comfort, for satisfactory speech intelligibility, and for pleasant listening conditions.

This book differs in one important respect from conventional text on acoustics in that it emphasizes the practical applications of electrical-circuit theory in the solution of a wide variety of problems. Wherever possible, the background of the electrical engineer and the communication physicist is utilized in explaining acoustical concepts.

The high-fidelity expert will find the chapters on loudspeaker enclosures horns, and rooms particularly interesting because they show how the performance of loudspeakers either in baffles or attached to horns may be accurately and simply calculated. These chapters also illustrate the necessity of considering in design the over-all system, including the amplifier, the loudspeakers, the baffle or horn and considering also the room in which they are to be operated. Numerical examples and summary charts are given to facilitate applications of this material to music-reproduction systems.

In view of the increased interest in noise control, the author has kept this subject in mind in writing Chapters 1, 2, 4 and 10 to 13. These chapters served as the basis of a special summer program on noise reduction at M.I.T. in 1953. The material of Chapters 11 and 13 is new, and it is hoped that it will be of value to those interested in noise and its effect on human beings. In short, the engineer or scientist who wishes to practice in the field of acoustics and who does not intend to confine his efforts to theoretical matters must know the material of this text.

Problems for each chapter are included at the end of the text for use by the student. Reference to collateral reading in English are given in the text, although no attempt has been made to give a bibliography of the primary sources of material. Suggestions to instructors for best use of the text are given immediately after this preface.

The author wishes to express his deep appreciation to Francis M. Wiener and Rudolph H. Nicholas, Jr. for their assistance in the detailed review and editing of the text and the preparation of some original material. Many members of the Acoustics Laboratory at M.I.T. have read one or more chapters and have given valuable assistance to the author. Of these, particular mention is made of Mary Anne Summerfield, Walter A. Rosenblith, Kenneth N. Stevens, Jerome R. Cox, Jordan J. Baruch, Joanne J. English, and Norman Doelling. The illustrations are due to the highly capable and untiring efforts of Clare Twardzik. The author is deeply indebted to his typist, Elizabeth H. Jones, to his secretary, Lydia Bonazzoli, and to his wife, Phyllis, who made it possible for him to complete the text within a reasonably short span of time.

Leo I. Beranek

Preface to the ASA Edition

With the advent of the compact disc, with miniature high-fidelity systems ambulating everywhere, and with emphasis on combination voice and data in worldwide digital and telephone networks, electroacoustics is a subject more vital today than it was three decades ago.
The heart of *Acoustics*, the first three-fourths of the text, Parts I--XXIV, is still valid. These parts encompass fundamental acoustics, principles of electro-mechano-acoustical circuits, radiation of sound, acoustic elements, microphones, loudspeakers, and their enclosures, and sound in rooms. Even so, the literature on microphones, loudspeakers and rooms has increased several times over since publication of the original volume. In Appendix III I have assembled for all chapters a representative selection of textbooks and articles that have appeared since about 1950, which contains, at various technical levels, the accomplishments leading to and the trends of today. I have chosen not to list every article published, nor to include literature in foreign languages. The intent is to supply supplementary reading in English.

Originally, a primary desire of the author was to help the student, engineer and acoustical consultant visualize better how to design an audio system to achieve the elusive goal of "high fidelity" sound reproduction. The medium I chose for achieving that result is the schematic circuit, analogous to that used in electronics, but differing from prior literature by combining into one diagram the necessary electrical, mechanical, and acoustical components, including the transduction process. An examination of the literature seems to indicate that one result of that effort was to stimulate the development of small loudspeaker enclosures, which in most locations have replaced the once ever-expanding "woofer" boxes.

A large proportion of the leading writers on loudspeaker system design in the last fifteen years, including E.M. Villchur, A.N. Thiele, R.H. Small, J.R. Ashley, A.D. Broadhurst, S. Morita, N. Kyouno, A.L. Karminsky, J. Merhaut, R.F. Allison, R. Berkovitz, and others, have used the middle chapters of this book as their starting point. In other words, a knowledge of the principles taught here has been a preface to their progress. I hold no particular brief for Chapter 11, part XXV, through Chapter 13. My later text, *Noise and Vibration Control* (McGraw-Hill, New York, 1971), treats this material in more detail benefiting from nearly twenty years of intervening progress in the field. The engineer interested in noise control should, perhaps, consider *Acoustics* and *Noise and Vibration Control* as Volumes I and II on the subject. The supplementary literature of the last 15 years on noise control, much of which is listed in Appendix III of this reprint, is not too formidable to peruse. Finally, I have made corrections to all the known errata in the book.

I wish to thank the Acoustical Society of America for their interest in reprinting *Acoustics*. I hope their faith in this portion of the acoustical literature is substantiated by the assistance it may give students and engineers in learning and practicing in the field of electroacoustics.

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