Fundamentals of Physical Acoustics

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Book review

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This book is an excellent piece of work. The text is extremely clear and goes a long way towards meeting the declared pedagogical target. The author has written a comprehensive text. The proportions of equations and explanations/interpretations are particularly well balanced. Throughout the book, the context and the validity domain for any equation derived are clearly stated. No doubt this book will be of invaluable help for students, academics and engineers. The structure of the book has a peculiar recursive pattern. Several topics are treated in each chapter, but these topics are the main subjects themselves of subsequent chapters (which can sometimes be found after several intermediate chapters). Although this means that the author returns to a subject more than once, no impression of redundancy comes out from the reading. This is due to a careful choice of the examples and the different angles from which the problems are viewed. The way in which the book is structured has a beneficial effect and undoubtedly participates in enhancing the pedagogical content. Essentially, each subject is treated in detail several times, thus giving the reader the opportunity to assimilate the concepts while still progressing in their discovery. Moreover the presentation and the layout of the book are excellent.

The fundamental concepts of Acoustics are introduced in Chapters 1and 2. Chapter 1 is fairly qualitative and presents the main aspects of Physical Acoustics with the minimum of Mathematics. The reader is not 'drowned' by equations, in being introduced to the basic principles that underpin Acoustics. Particularly remarkable, in Chapter 1, is the excellent description of the Lagrange and Euler systems of coordinates. The examples given help to visualise the difference between the two systems. Also, the complex radiation impedance is described very well. The numerous footnotes in the book are helpful and pertinent. They enlarge the scope and provide useful information or explanations without interfering with the developments. Chapter 2 revisits Chapter 1in more detail. As mentioned by the author in the forewords, the role and position of Chapter 2 have a pedagogical motivation. Various extensions of the basic linear equation of wave propagation are presented. These extensions are necessary for treating the main situations that can be encountered in Engineering Acoustics. This idea is excellent and is beneficial to the clarity and comprehension. Although more mathematics is involved, the pedagogical skill of the author makes it agreeable to read.

Chapters 3–5 introduce the reader to problems of wave reflection and transmission at the interface between two fluids. A sudden change in cross-section area in a duct has the same effect on the transmission loss as a variation in impedance. The mathematical formulation of this problem is similar to that of waves at interfaces and the problem of wave propagation in ducts with variations in cross-section is also studied in Chapters 3 and 4. In Chapter 3, the normal incidence reflection and transmission coefficients for the pressure and for the sound power are derived in the time domain. The introduction of complex impedance is delayed and the expressions obtained are simpler. Therefore, a better understanding of the phenomena is gained. In addition, the reflection and transmission for waves of arbitrary waveform can be studied more easily. Harmonic time dependence is studied in Chapter 4 where complex reflection and transmission coefficients are considered. Chapter 4 is important as many Engineering applications involve a study in the frequency domain. Although useful problems are investigated, this reader feels that a bit more could perhaps have been written to introduce the standing waves since they are rather important in acoustics and vibration theory. Chapter 5 is concerned with transmission at oblique incidence and the refraction law is established. This chapter represents a good introduction to the ray theory presented in Chapter 8.

Chapter 6 is an introduction to vibration theory, normal modes, waveguides and dispersion. The description of the phenomena is very good. In particular, the description of the relationship between free and forced vibrations and the associated resonance frequencies is excellent. The phase velocity, the group velocity and wave dispersion are general concepts, not restricted to waveguides. These could perhaps have been introduced more generally to present the opportunity to discuss phenomena related to dispersion, such as wave packets and group velocity, the frequency content of a signal and the effect of dispersion on temporal waveforms, to a greater extent.

Chapters 7 and 8 are concerned with applications of a particular differential equation established in the linear approximation: the Webster horn equation. Although these two chapters deal with totally different subjects, propagation in ducts with varying cross section and vertical propagation in media with a (vertical) gradient of the properties are governed by the same differential equation. A general method for integrating this equation is presented and applied to both cases. When the propagation is not in the direction of the gradient, a differential form of Snell's law presented in Chapter 5 is used. This law is the origin of the ray theory presented in the second part of Chapter 8.

Chapter 9 reviews the main mechanisms of wave attenuation in fluids. This chapter is extremely well structured and is possibly the clearest. The diagram on page 299 is excellent. It gives a global view of the problem, which is excellent for serving the pedagogical purpose (it should always be like that in any book). It shows how the equations developed in the first chapters relate to each other and the origin of the attenuation coefficient and the velocity. This diagram is very general and it is believed that it could have been introduced even earlier. The relationship between the different contributions to wave attenuation and the validity of their superposition is also well explained (see footnote). The summary at the end of the chapter will be particularly useful for scientists.

Chapters 10 and 11 deal with spherical waves, cylindrical waves, sound radiation and circular membranes. By nature, these subjects are mathematical and it is necessary to introduce an array of spherical and cylindrical functions. All the appendices are very useful. However, perhaps there is an imbalance or injustice in the fact that an entire appendix is dedicated to the solution of Legendre's equation while none is devoted to Bessel, Neuman or Hankel functions. Is it the fact that Legendre polynomials appear in the general solution for spherical waves that influenced the author's decision to write appendix D?

The last chapters correspond to applications of previous chapters. Waveguides are important for example in flow duct acoustics or in building acoustics in general. Chapter 12 is a development of this subject, which is introduced in Chapter 6. The previous chapter on waves in cylindrical co-ordinates permits the study of cylindrical waves in circular waveguides or between infinite parallel planes, which was not possible in Chapter 6. As an application of the monopole source radiator, Chapter 13 introduces the Rayleigh integral (almost already there in Chapter 10) and applies it to the sound radiation from a piston. Starting from the study of a ring piston, the full disk piston is studied in the baffled case. The near field, the far field and the directivity are described. The Rayleigh distance is also introduced and physical interpretations are given. The fluid loading is accounted for through the calculation of the radiation impedance at the surface of the piston. Other cases are studied such as a nonharmonic translation velocity or a nonuniform piston for which the velocity depends on the position on the surface. The non baffled case is not treated but evoked in the introduction. Chapter 14 is concerned with diffraction. The introductory description of the phenomenon is particularly good. The Helmholtz–Kirchhoff integral theorem is presented and applied to basic sample problems. The chapter ends with Babinet's principle on the complementarity of diffracting objects. Finally, Chapter 15 studies the radiation of arrays of equally spaced point sources in line configuration and the radiation pattern as a function of the wavenumber and separation distance. Again, the explanations are clear and pedagogically very good. In the limit of infinite number of sources and when the separation distance tends to zero, it is shown in an elegant way, that the same expression for the directivity function is obtained as that obtained from the integration over a line source. This integration is similar to the calculation done for a circular piston in Chapter 13.

This comprehensive and pedagogically-sound book is a rigorous introduction to physical acoustics. Well suited for graduate students, it should be very useful also to academics and engineers.

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