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Book review

H.J. Pain, The Physics of Vibrations and Waves, 6th ed., Wiley, New York, ISBN 0470012951 (Hardback), 047001296X (Paperback), 2005 (576pp).

This book, aimed primarily at first-year physics undergraduates, is a substantial introduction to the basic ideas of wave theory. Important applications considered in detail are waves in fluids and solids (including crystals), waves on a string, electromagnetic waves as described by Maxwell's equations, and the basics of the quantum theory of electron waves and phonons as described by Schrödinger's equation. Thus acoustics receives its full share of attention, but many other types of wave are considered besides. Although most of the waves studied are governed by linear equations, the two final chapters treat nonlinear waves, with many examples: acoustic examples considered include wave steepening and N-wave formation, together with a full account of the jump conditions across a shock and their consequences; some 'real fluid dynamics' examples of nonlinearity are Couette flow, Rayleigh–Bénard convection, and solitons governed by the Korteweg–de Vries equation; and further examples of nonlinearity are provided by nonlinear springs, electrical relaxation oscillations governed by Van der Pol's equation, and chaos in population biology. Basic mathematical techniques, notably the calculation of eigenvalues, eigenvectors, and normal coordinates, and the theory of Fourier series and transforms, are developed in detail from first principles when they are required.

The book is clear and student-friendly, and contains a large selection of interesting problems, at an appropriate level of difficulty (i.e., not excessively difficult). It is easy to see why the book has found favour over many editions. One might ask how suitable the text is for mechanical engineering students who are going to concentrate on the mainstream topics covered in the Journal of Sound and Vibration. Except for one omission (noted below) I believe the book is highly suitable: if the fluid dynamics, acoustics and mathematical parts only are read, the text is completely intelligible, and any other parts could be read for general education in wave theory, or as needed for a particular application. Indeed, some researchers in applied acoustics make good use of ideas developed primarily by physicists, and the text would make a suitable starting point for the students of such researchers.

The omission referred to above is that the book contains no mention of bending waves in beams or plates. Thus although the title of the book contains the word 'vibrations', the book does not cover what might be termed the ordinary vibrations of everyday life, such as the vibration of a wall panel or a window pane, or a panel in a car. The basic equation for such vibrations, namely Euler's beam equation containing the fourth spatial derivative of the transverse displacement, is not only practical but is also well suited to the study of dispersive waves. The student reading the book might form the mistaken idea that all waves are governed by first- or second-order equations; I believe that the only derivative higher than the second in the book is that in the dispersive term in the Korteweg–de Vries equation, i.e., a third-order spatial derivative.

A reviewer is bound to disagree with a few points in even a first-year book. I could not accept the statement on page 110 that for a monochromatic wave the group velocity and the phase velocity are equal. The reason is that the group velocity is, in essence, the energy propagation velocity, and for a monochromatic wave in a dispersive system the energy velocity most certainly does not equal the phase velocity. The fact that a monochromatic wave is not a group of waves can undoubtedly be very confusing linguistically in discussion of group velocity, but has no bearing on the physics of the matter, notwithstanding the traditional introduction of the concept of group velocity by considering two monochromatic waves of neighbouring wavenumber and frequency. A full discussion of the group velocity for a perfectly sinusoidal wave of fixed wavenumber and

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fixed frequency, emphasising the physics of this potentially tricky topic, is given in Lighthill (1978), Waves in Fluids (CUP), e.g. on pages 239 and 258.

A slip occurs on page 515 after the derivation of the equation $\eta_t + c_0\eta_x + b\eta\eta_x = 0$. It is stated that, since interest lies in nonlinear effects, removal of the linear contribution to the equation gives $\eta_t + b\eta\eta_x = 0$. This is not correct: in general, $c_0\eta_x$ has the same order of magnitude as at least one other term in the original equation. A correct statement would be that if a coordinate $X = x - c_0 t$ is used to convert to a frame of reference moving with speed c_0 then the resulting equation is $\eta_t + b\eta\eta_X = 0$.

I would not wish to dwell on these last points. This is an excellent textbook, full of interesting material clearly explained, and fully worthy of being studied by future contributors to the Journal of Sound and Vibration.

C.J. Chapman, Department of Mathematics, University of Keele, Keele, Staffordshire ST5 5BG, UK; E-mail: c.j.chapman@maths.keele.ac.uk. John Chapman is a Professor of Applied Mathematics at Keele University. His 'High Speed Flow' (2000) is published by Cambridge University Press in the series Cambridge Texts in Applied Mathematics.