9

Introduction

Any material medium, whether in its fluid (i.e. gaseous or liquid), or its solid (or condensed) state, is capable of carrying acoustic or elastic waves. This kind of mechanical disturbance occurs when the elementary building blocks of matter are, by some cause, displaced out of their equilibrium position and try to return to this position under the influence of restoring forces. In this respect, acoustic waves (in fluids) and elastic waves (in solids) differ from electromagnetic waves in that the latter can also be present *in vacuo* (i.e., in the absence of matter), whereas the former two cannot. In the present part of the *Handbook*, the investigation of the properties of elastic waves in solids is our main concern; the properties of acoustic waves in fluids are discussed in Part 1. Elastic waves in solids are also denoted as *elastodynamic waves*; elastic waves in the Earth are also denoted as *seismic waves*.

When following an elastic wave on its course, we start with its *excitation* by an acoustic source or transmitting device (an explosive source or a mechanical plate vibrator for seismic exploration, an electromechanical transducer for sonic or ultrasonic well logging or nondestructive evaluation of a mechanical structure, an earthquake). Once it has been generated, the wave *propagates* along a certain, more or less confined, path from the source to the receiver. Depending on the properties of the medium through which the wave passes, this propagation can lead to continuous *refraction* by spatial and/or temporal changes in the medium (for example, the different layers of the Earth), to *reflection* against and *transmission* across interfaces between different media, or to discontinuous *scattering* or *diffraction* by objects whose elastic properties show a contrast with those of their surroundings. Finally, the wave motion is *received* by an acoustic receiving device (a geophone, an electromechanical transducer, a seismograph). Figure 9.1 illustrates these different aspects.

Each of these aspects is the subject of extensive theoretical and experimental investigation. Usually, when the attention is focused on a particular detail, the remaining circumstances are chosen as simply as possible. For example, when one wants to investigate the directional characteristics of an acoustical or a seismic source, the surrounding medium will be assumed to be of the utmost simplicity as far as its elastic properties are concerned, and of infinite extent. When studying refraction phenomena during the propagation of an elastic wave, the source will be taken to be a simple one (mostly a point source, i.e., a source whose dimensions are negligibly small compared to the other characteristic dimensions of the configuration under investigation), while the influence of the receiver will be neglected altogether (by taking it to be a point receiver). When studying the influence of a scattering configuration, both the surrounding medium and the kind of excitation will be taken to be very simple ones. All these simplifications

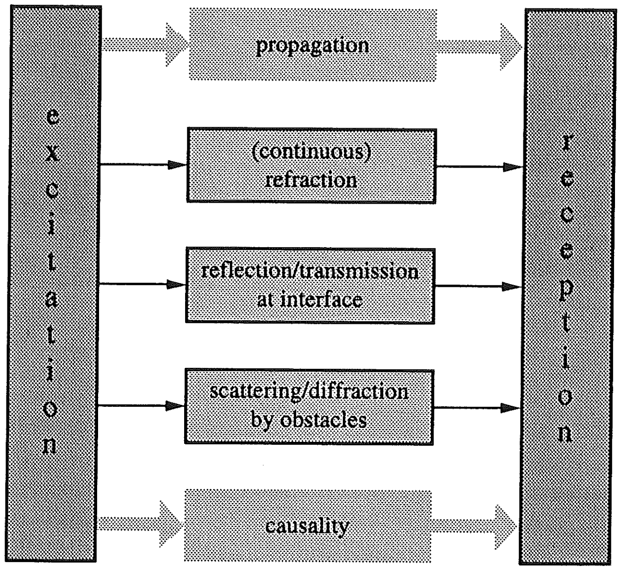

Figure 9.1. Elastic wave phenomena on their course from source to receiver.

are dictated by the impossibility of accounting for the influence of all parameters simultaneously, even with present-day, large-capacity, high-speed computers. It is the task of the elastodynamic scienstist or engineer to put the results of the partial model studies together in a judicious way in order to be able to compose a judgement of the behaviour of elastic waves in the more complicated situations met in practice.

The practical applications of elastic waves are widespread, and the number of fields in which they are used is ever increasing. First of all we mention the field of *exploration geophysics*, be it in surface seismics, vertical seismic profiling, cross-borehole seismics, or borehole acoustics. Here, acoustic and elastic waves are used to map the subsurface structure of the Earth in the search of fossil energy resources (coal, oil, natural gas). Furthermore, the *non-destructive evaluation* of materials and of mechanical structures makes use of elastic waves to a large extent. The scattering of these waves by interior defects (inclusions, bubbles, cracks) makes the presence of these defects detectable at the surface of the structure, which surface is accessible for carrying out the necessary measurements. Finally, *earthquake engineering*, i.e., the design of earthquake- resistant structures, requires the knowledge of the properties of elastic waves in the Earth's crust. In Figure 9.2 the different applications are listed.

We shall develop the theory of elastodynamic radiation on a *macroscopic* scale. This implies that in all elastic wave interactions many elementary building blocks of matter are involved and that the exchange of energy takes place through large numbers of energy quanta. Occasionally, we shall use microscopic considerations to elucidate the underlying physical picture of the macroscopic phenomena. Classical treatises on the subject are those by Lord Rayleigh (1945), Love (1959) and Morse and Ingard (1968). Other useful material can be found in the textbooks by Achenbach (1973), Miklowitz (1978), Aki and Richards (1980) and in the series edited by Mason (1964-...).

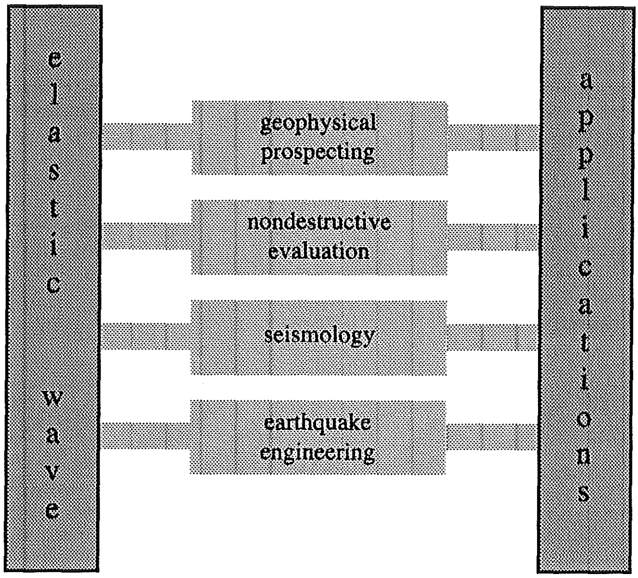

Figure 9.2. Applications of elastic waves.

As in any kind of wave motion, the physical quantities that describe the elastic wave motion depend on position and on time. Their time dependence in the domain where the source is acting is imposed by the excitation mechanism of the source. The subsequent dependence on position and time elsewhere is governed by the pertaining propagation and scattering laws, together with the principle of causality.

Exercises

Exercise 9.1

Make a list of the names and the SI-units (written in full with the corresponding symbols) of the elastic wave-field quantities occurring in the chapters of Part 2. (*Hint:* Consult the General Introduction for the pertaining international standardisation.)

References

Achenbach, J.D., 1973, *Wave Propagation in Elastic Solids*, Amsterdam: North-Holland.
Aki, K., and Richards, P.G., 1980, *Quantitative Seismology*, San Francisco: Freeman.
Love, A.E.H., 1959, *A Treatise on the Mathematical Theory of Elasticity*, Cambridge: Cambridge University Press, 4th edn.
Mason, W.P., (Ed.), 1964-..., *Physical Acoustics*, New York: Academic Press.
Miklowitz, J., 1978, *The Theory of Elastic Waves and Waveguides*, Amsterdam: North-Holland.
Morse, P.M., and K.V. Ingard, 1968, *Theoretical Acoustics*, New York: McGraw-Hill.
Strutt, J.W., 1945, *The Theory of Sound* (Lord Rayleigh), New York: Dover.