Principles of Seismology

Second Edition

The second edition of Principles of Seismology has been extensively revised and updated to present a modern approach to observation seismology and the theory behind digital seismograms. It includes: a new chapter on earthquakes, Earth's structure and dynamics; a considerably revised chapter on instrumentation, with new material on processing of modern digital seismograms and a list of website hosting data and seismological software; and 100 end-of-chapter problems. The fundamental physical concepts on which seismic theory is based are explained in full detail with step-by-step development of the mathematical derivations, demonstrating the relationship between motions recorded in digital seismograms and the mechanics of deformable bodies. With chapter introductions and summaries, numerous examples, newly drafted illustrations and new color figures, and an updated bibliography and reference list, this intermediate-level textbook is designed to help students develop the skills to tackle real research problems.

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Preface and Acknowledgments

A second edition of this textbook, first published 17 years ago, is a wonderful opportunity to review its contents and improve its pedagogical orientation, in view of the many comments and interactions received, teaching experience, and experimental progress in seismology over the intervening years. Seismology is the science of earthquakes, which are both natural disasters profoundly affecting human lives, and a subject of study through application of the principles of the physical sciences. These two aspects are linked, since an important aim of the study of seismology is to mitigate the terrible effects of earthquakes through a more complete knowledge of their nature. Seismology provides us also with a powerful instrument to study the constitution and dynamics of the Earth. To emphasize these different aspects of seismology, Chapter 2 has been added to present, as an introduction, the complex phenomenon of earthquakes from a narrative point of view. As a physical science, the fundamentals of seismology are based on analysis of the seismic waves produced by earthquakes and registered by seismographs. The importance of this aspect is shown by presenting the analysis of seismographic digital data in Chapter 3, so that it can be used in subsequent chapters. This is a unique feature not present in other texts on seismology. Thus, this approach has been used in the new edition. The text is at an introductory level for students in the last years of the European Licentiate and the first year of Masters programs or American upper-division undergraduate courses and first graduate courses, and at similar levels of study in other countries. As a first book, no previous knowledge of seismology, as such, is assumed of the student. The book's emphasis, as indicated by its title, is on the fundamental physical principles which constitute the basis of the analysis of seismic waves and their basic development. In consequence, a number of topics have been selected. It has been noticed that sometimes even graduate students lack a true grasp of the fundamental physical principles underlying some aspects of seismology. In this book, the most fundamental concepts are, therefore, developed in detail, with their mathematical developments fully worked out. Simple cases, such as one-dimensional problems and those in liquid media, are used as introductory topics. In some instances, more difficult subjects are introduced, although not fully developed. In these cases references to more advanced books and articles are given where they can be found. In each chapter, problems are proposed, some of them are fully solved in the electronic material. As an innovation in this edition, for some of the problems seismogram digital data are used, which are given in the electronic material. Details of websites from where data and programs can be retrieved are provided. The reader can access the electronic material at www.cambridge.org/UdiasBuforn, and it is referenced in the text as EM.

The book presupposes a certain level of knowledge of mathematics and physics. Knowledge of mathematics at the level of calculus and ordinary and partial differential equations, as well as a certain facility for vector and tensor analysis, are assumed. Cartesian,

spherical, and cylindrical coordinates, and some functions such as Legendre and Bessel functions are used. Tensor index notation is used preferentially throughout the book. Fundamental ideas about certain mathematical subjects are given briefly in Appendixes 1 to 4. Basic knowledge of the mechanics of a continuous medium and of the theory of elasticity is also presupposed, but the reader is reminded about the basic equations of elasticity in Chapter 4 and for other topics is referred to textbooks on elasticity that are cited in the Bibliography.

Throughout the book there is an emphasis on the fundamental theoretical aspects of seismology and observations are treated briefly. Thus, some readers will miss discussion of recent results; we refer them to the excellent books by Lay and Wallace (1995) and Stein and Wysession (2003). Also, more advanced developments of the theory of wave propagation and generation are not treated; see, for example, Aki and Richards (1980), Ben Menahem and Singh (1981), and Dahlen and Tromp (1998). We hope that our book is a good introduction to these excellent advanced books. It is difficult to decide where to stop with subjects treated in a textbook that is designed as an introduction. We have selected to develop only, but with all mathematical detail, the very basic problems. In this sense, as was mentioned in the preface of the first edition, this book is different from those that already exist. The style and approach are also sometimes different, and reflect those of the authors.

After the introductory two chapters providing a short narrative presentation of the phenomenon of earthquakes, Chapter 3 gives the theory of seismographs and the analysis of seismograms in digital form. In this way digital seismograms can be used in subsequent chapters and problems thereby included. The following chapters are dedicated to the fundamentals of elasticity theory (Chapter 4), solutions of the wave equation (Chapter 5), the propagation of body waves (Chapters 6 and 7), ray theory (Chapters 8 to 11), and surface waves (Chapters 12 and 13), normal modes and free oscillations (Chapter 14), with an introduction to anelasticity and anisotropy (Chapter 15). Five chapters are devoted to the study of the earthquake source and the focal mechanism (Chapters 16 to 20). The final one (Chapter 21) introduces the reader to the problems of seismicity, seismotectonics, and seismic risk. Appendixes 1 to 4 cover some mathematical tools, Appendixes 5 to 7 give some helpful information. The Bibliography includes books on seismology and related topics. Other references cited in the text are given separately. Some books are listed as references, so one must use both lists.

The authors wish to thank in the first place all of our students over many years at the Universidad Complutense in Madrid, to whom we are indebted for their questions and suggestions, which have helped us to write this second edition, and for their patience during our lectures. We must thank also a long list of seismologists, some of them former students, who will be difficult to name without omissions, and we hope, therefore, that they will all feel included in our thanks. We thank IRIS (Incorporated Research Institutions for Seismology) for providing some of the digital seismograms used in examples and problems. Finally, we very much appreciate Cambridge University Press for offering to prepare this new edition.