Solved Problems in Geophysics

Solving problems is an indispensable exercise for mastering the theory underlying the various branches of geophysics. Without this practice, students often find it hard to understand and relate theoretical concepts to their application in real-world situations.

This book is a collection of nearly 200 problems in geophysics, which are solved in detail showing each step of their solution, the equations used and the assumptions made. Simple figures are also included to help students understand how to reduce a problem to its key elements. The book begins with an introduction to the equations most commonly used in solving geophysical problems. The subsequent four chapters then present a series of exercises for each of the main, classical areas of geophysics – gravity, geomagnetism, seismology and heat flow and geochronology. For each topic there are problems with different degrees of difficulty, from simple exercises that can be used in the most elementary courses, to more complex problems suitable for graduate-level students.

This handy book is the ideal adjunct to core course textbooks on geophysical theory. It is a convenient source of additional homework and exam questions for instructors, and provides students with step-by-step examples that can be used as a practice or revision aid.

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Preface

This book presents a collection of 197 solved problems in geophysics. Our teaching experience has shown us that there was a need for a work of this kind. Solving problems is an indispensable exercise for understanding the theory contained in the various branches of geophysics. Without this exercise, the student often finds it hard to understand and relate the theoretical concepts with their application to practical cases. Although most teachers present exercises and problems for their students during the course, the hours allotted to the subject significantly limit how many exercises can be worked through in class. Although the students may try to solve other problems outside of class time, if there are no solutions available this significantly reduces the effectiveness of this type of study. It helps, therefore, both for the student and for the teacher who is explaining the subject if they have problems whose solutions are given and whose steps can be followed in detail. Some geophysics textbooks, for example, F.D. Stacey, *Physics of the Earth*; G.D. Garland, *Introduction to Geophysics*; C.M. Fowler, *The Solid Earth: An Introduction to Global Geophysics*; and W. Lowrie, *Fundamentals of Geophysics*, contain example problems, and, in the case of Stacey's, Fowler's, and Lowrie's textbooks, their solutions are provided on the website of Cambridge University Press. The main difference in the present text is the type of problems and the detail with which the solutions are given, and in the much greater number.

All the problems proposed in the book are solved in detail, showing each step of their solution, the equations used, and the assumptions made, so that their solution can be followed without consulting any other book. When necessary, and indeed quite often, we also include figures that allow the problems to be more clearly understood. For a given topic, there are problems with different degrees of difficulty, from simple exercises that can be used in the most elementary courses, to more complex problems with greater difficulty and more suitable for teaching at a more advanced level.

The problems cover all parts of geophysics. The book begins with an Introduction (Chapter 1) that includes the equations most used in solving the problems. The idea of this chapter is not to develop the theory, but rather to simply give a list of the equations most commonly used in solving the problems, at the same time as introducing the reader to the nomenclature. The next four chapters correspond to the division of the problems into the four thematic blocks that are classic in geophysics: gravity, geomagnetism, seismology, and heat flow and geochronology. We have not included problems in geodynamics, since this would depart too much from the approach we have taken, which is to facilitate comprehension of the theory through its application to specific cases, sometimes cases which are far from the real situation on Earth. Indeed, some of the problems may seem a bit artificial, but their function is to help the student practise with what has been seen in the theory. Neither did we want to include specific problems of geophysical prospecting as this would have considerably increased the length of the text, and moreover some of the topics that would be covered in prospecting, such as gravimetric and geomagnetic anomalies, are already included in other sections of this work.

Chapter 2 contains 68 problems in gravity divided into five sections. The first section is dedicated to the terrestrial geoid and ellipsoid, proposing calculations of the parameters that define them in order to help better understand these reference surfaces. The second corresponds to calculating the gravitational field and potential for various models of the Earth, including the existence of internal structures. Gravity anomalies are dealt with in the third section, with a variety of problems to allow students to familiarize themselves with the corrections to the observed gravity, with the concept of isostasy, and with the Airy and Pratt hypotheses. The fourth section studies the phenomenon of the Earth's tides and their influence on the gravitational field. The last section is devoted to the observations of gravity from measurements made with different types of gravimeters and the corrections necessary in each case. We also include the application of these observations to the accurate determination of different types of height.

Chapter 3 contains 42 problems in geomagnetism divided into five sections. The first is devoted to the main (internal) field generated by a tilted dipole at the centre of the Earth. It includes straightforward problems that correspond to the calculation of the geomagnetic coordinates of a point and the theoretical components of the magnetic field. This section also introduces the student to the use of the principal units used in geomagnetism. The second considers the magnetic anomalies generated by different magnetized bodies and their influence on the internal field. The third section is devoted to the external field and its variation with time. In the fourth section, we propose problems of greater complexity involving the internal field, the external field, and anomalous magnetized bodies at the same time. The last section is devoted to problems in paleomagnetism.

Chapter 4 contains 69 problems in seismology divided into seven sections. The first presents some simple exercises on the theory of elasticity. The second addresses the problem of the propagation of seismic energy in the form of elastic waves, resolving the problems on the basis of potentials, and calculating the components of their displacements. We study the reflection and refraction of seismic waves in the third section. The fourth is devoted to the problem of wave propagation using the theory of ray paths in a plane medium of constant and variable velocity of propagation. The fifth studies the problem of the propagation of rays in a spherical medium of either constant or variable propagation velocity, with the calculation of the travel-time curves for both plane and spherical media. The sixth section contains problems in the propagation of surface waves in layered media. The seventh section is devoted to problems of calculating the focal parameters and the mechanism of earthquakes.

Chapter 5 includes 11 problems in heat flow with the propagation of heat in plane and spherical media, and seven problems in geochronology involving the use of radioactive elements for dating rocks.

Finally, we provide a bibliography of general textbooks on geophysics and of specific textbooks for the topics of gravity, geomagnetism, and seismology. We have tried to include only those most recent and commonly used textbooks which are likely to be found in university libraries.

In sum, the book is a university text for students of physics, geology, geophysics, planetary sciences, and engineering at the undergraduate or Master's degree levels. It is intended to be an aid to teaching the subjects of general geophysics, as well as the specific topics of gravity, geomagnetism, seismology, and heat flow and geochronology contained in university curricula.

The teaching experience of the authors in the universities of Barcelona, Extremadura, and the Complutense of Madrid highlighted the need for a work of this kind. This text is the result of the teaching work of its authors for over 20 years. Thanks are due to the generations of students over those years who, with their comments, questions, and suggestions, have really allowed this work to see the light. We are also especially grateful to Prof. Greg McIntosh who provided us with some problems on paleomagnetism, to Prof. Ana Negredo for her comments on heat flow and geochronology problems, and to Dr R.A. Chatwin who worked on translating our text into English.

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