

Seismic wave equation

- Start with Newton $F = ma$

$$F = \rho \frac{\partial^2 u}{\partial t^2}$$

- Add 'constitutive equation' to relate stress to strain to displacement

$$\rho \ddot{u} = (\lambda + 2\mu) \nabla \nabla \cdot u - \mu \nabla \times \nabla \times u$$

The Seismic Wave Equation

**Weijia Sun, Erdinc Saygin, Zengxi
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Yu, Kazunori Yoshizawa**

The Seismic Wave Equation:

Numerical Modeling of Seismic Wave Propagation Johan O. A. Robertsson, 2012 Modeling of seismic wave propagation is a core component in almost every aspect of exploration seismology ranging from survey design methods to imaging and inversion algorithms Since SEG published a reprint volume on numerical modeling in 1990 the following two decades showed a step change in the application and use of full wave equation modeling methods enabled by the tremendous increase in available computational power Full waveform inversion reverse time migration and 3D elastic finite difference synthetic data generation are examples of modeling applications that are currently having a fundamental impact on our business In Numerical Modeling of Seismic Wave Propagation Gridded Two way Wave equation Methods readers will find many of the well known and referenced papers from the exploration seismic community as well as some of the key papers that have impacted other fields of seismology Because the modeling literature is vast we have limited the scope of the reprint volume to papers over the last two decades on modeling methods based on the full wave equation The reprint volume will be of particular interest to researchers and practitioners interested in modeling methods and their applications The searchable CD includes the 114 page book of abstracts and the full papers

Numerical Modeling of Seismic Wave Propagation K. R. Kelly, K. J. Marfurt, 1990

Seismic Modeling and Imaging with the Complete Wave Equation Ralph Phillip Bording, Larry R. Lines, 1997 Seismic modeling and imaging of the earth's subsurface are complex and difficult computational tasks The authors present general numerical methods based on the complete wave equation for solving these important seismic exploration problems

Seismic Waves and Rays in Elastic Media M.A. Slawinski, 2003-08-04 This book seeks to explore seismic phenomena in elastic media and emphasizes the interdependence of mathematical formulation and physical meaning The purpose of this title which is intended for senior undergraduate and graduate students as well as scientists interested in quantitative seismology is to use aspects of continuum mechanics wave theory and ray theory to describe phenomena resulting from the propagation of waves The book is divided into three parts Elastic continua Waves and rays and Variational formulation of rays In Part I continuum mechanics are used to describe the material through which seismic waves propagate and to formulate a system of equations to study the behaviour of such material In Part II these equations are used to identify the types of body waves propagating in elastic continua as well as to express their velocities and displacements in terms of the properties of these continua To solve the equations of motion in anisotropic inhomogeneous continua the high frequency approximation is used and establishes the concept of a ray In Part III it is shown that in elastic continua a ray is tantamount to a trajectory along which a seismic signal propagates in accordance with the variational principle of stationary travel time

Seismic Wave Theory Edward S. Krebes, 2019-03-28 Perfect for senior undergraduates and first year graduate students in geophysics physics mathematics geology and engineering this book is devoted exclusively to seismic wave theory The result is an invaluable teaching tool with its detailed derivations of formulas clear explanations of topics exercises along

with selected answers and an additional set of exercises with derived answers on the book's website. Some highlights of the text include a review of vector calculus and Fourier transforms and an introduction to tensors which prepare readers for the chapters to come and a detailed discussion on computing reflection and transmission coefficients a topic of wide interest in the field a discussion in later chapters of plane waves in anisotropic and anelastic media which serves as a useful introduction to these two areas of current research in geophysics. Students will learn to understand seismic wave theory through the book's clear and concise pedagogy.

Reflection Seismology Yang Wencai, 2013-09-18 Authored by a geophysicist with more than 50 years of experience in research and instruction. Reflection Seismology: Theory, Data Processing and Interpretation provides a single source of foundational knowledge in reflection seismology principles and theory. Reflection seismology has a broad range of applications and is used primarily by the oil and gas industry to provide high resolution maps and build a coherent geological story from maps of processed seismic reflections. Combined with seismic attribute analysis and other exploration geophysics tools it aids geologists and geo engineers in creating geological models of areas of exploration and extraction interest. Yet as important as reflection seismology is to the hydrocarbon industry it's difficult to find a single source that synthesizes the topic without having to wade through numerous journal articles from a range of different publishers. This book is a one stop source of reflection seismology theory helping scientists navigate through the wealth of new data processing techniques that have emerged in recent years. Provides geoscientists and geo engineers with a theoretical framework for navigating the rapid emergence of new data processing techniques. Presents a single source of reflection seismology content instead of a scattering of disparate journal articles. Features more than 100 figures, illustrations and working examples to aid the reader in retaining key concepts. Arms geophysicists and geo engineers with a solid foundation in seismic wave equation analysis and interpretation.

Applied Seismic Wave Theory A. J. Berkhout, 1987

Full Seismic Waveform Modelling and Inversion Andreas Fichtner, 2010-11-16 Recent progress in numerical methods and computer science allows us today to simulate the propagation of seismic waves through realistically heterogeneous Earth models with unprecedented accuracy. Full waveform tomography is a tomographic technique that takes advantage of numerical solutions of the elastic wave equation. The accuracy of the numerical solutions and the exploitation of complete waveform information result in tomographic images that are both more realistic and better resolved. This book develops and describes state of the art methodologies covering all aspects of full waveform tomography including methods for the numerical solution of the elastic wave equation, the adjoint method, the design of objective functionals and optimisation schemes. It provides a variety of case studies on all scales from local to global based on a large number of examples involving real data. It is a comprehensive reference on full waveform tomography for advanced students, researchers and professionals.

Waves And Rays In Elastic Continua Michael A Slawinski, 2010-09-09 The present book which is the second and significantly extended edition of the textbook originally published by Elsevier Science emphasizes

the interdependence of mathematical formulation and physical meaning in the description of seismic phenomena Herein we use aspects of continuum mechanics wave theory and ray theory to explain phenomena resulting from the propagation of seismic waves The book is divided into three main sections Elastic Continua Waves and Rays and Variational Formulation of Rays There is also a fourth part which consists of appendices In Elastic Continua we use continuum mechanics to describe the material through which seismic waves propagate and to formulate a system of equations to study the behaviour of such a material In Waves and Rays we use these equations to identify the types of body waves propagating in elastic continua as well as to express their velocities and displacements in terms of the properties of these continua To solve the equations of motion in anisotropic inhomogeneous continua we invoke the concept of a ray In Variational Formulation of Rays we show that in elastic continua a ray is tantamount to a trajectory along which a seismic signal propagates in accordance with the variational principle of stationary traveltime Consequently many seismic problems in elastic continua can be conveniently formulated and solved using the calculus of variations In the Appendices we describe two mathematical concepts that are used in the book namely homogeneity of a function and Legendre's transformation This section also contains a list of symbols

Scattering and Attenuation of Seismic Waves, Part II WU,AKI,2013-11-21 Reprint from Pure and Applied

Geophysics PAGEOPH Volume 131 1989 No 4 *Seismic Wave Propagation in the Earth* Andrzej Hanyga,E. Lenartowicz,J. Pajchel,1985 This volume contains an extensive presentation of the theory phenomenology and interpretation of seismic waves produced by natural and artificial sources Each theoretical topic discussed in the book is presented in a self contained and mathematically rigorous form yet without excessive demands on the reader's mathematical background It is the only book to include such a complete presentation of the mathematical background and modern developments of the WKBJ theory of seismic waves and detailed discussions of its wide ranging applications The book will therefore be useful to postgraduate students and research workers specialising in seismic wave theory theoretical seismology electromagnetic wave theory and other fields of wave propagation theory **Introduction to Seismology** Peter M. Shearer,2009-06-11 This book provides an approachable and concise introduction to seismic theory designed as a first course for undergraduate students It clearly explains the fundamental concepts emphasizing intuitive understanding over lengthy derivations Incorporating over 30% new material this second edition includes all the topics needed for a one semester course in seismology Additional material has been added throughout including numerical methods 3 D ray tracing earthquake location attenuation normal modes and receiver functions The chapter on earthquakes and source theory has been extensively revised and enlarged and now includes details on non double couple sources earthquake scaling radiated energy and finite slip inversions Each chapter includes worked problems and detailed exercises that give students the opportunity to apply the techniques they have learned to compute results of interest and to illustrate the Earth's seismic properties Computer subroutines and datasets for use in the exercises are available at www.cambridge.org/shearer *Transient Waves in Visco-Elastic Media* Norman

Ricker,2012-12-02 Developments in Solid Earth Geophysics 10 Transient Waves in Visco Elastic Media deals with the propagation of transient elastic disturbances in visco elastic media More specifically it explores the visco elastic behavior of a medium whether gaseous liquid or solid for very small amplitude disturbances This volume provides a historical overview of the theory of the propagation of elastic waves in solid bodies along with seismic prospecting and the nature of seismograms It also discusses the seismic experiments the behavior of waves propagated in accordance with the Stokes wave equation and wavelet functions and their polynomials The book explains the laws of propagation of seismic wavelets and seismic ray paths as well as the equations of wavelet propagation the velocity type seismic wavelet and the spectrum of the wavelet It discusses the motion of a mechanical seismograph disturbed by extraneous forces or motions It also provides information on the differential equation describing the motion of a galvanometer laboratory studies of wavelet contraction and characteristics of a wavelet contractor amplifier Furthermore the book explains the experimental studies of the primary seismic disturbance and internal friction This monograph is a valuable source of information for physicists students who want to pursue a career in geophysics or selenophysics and those who actively working in these fields **Seismic Wave**

Propagation and Scattering in the Heterogenous Earth Haruo Sato,Michael C. Fehler,2008-12-17 Seismic waves generated both by natural earthquakes and by man made sources have produced an enormous amount of information about the Earth s interior In classical seismology the Earth is modeled as a sequence of uniform horizontal layers or sperical shells having different elastic properties and one determines these properties from travel times and dispersion of seismic waves The Earth however is not made of horizontally uniform layers and classic seismic methods can take large scale inhomogeneities into account Smaller scale irregularities on the other hand require other methods Observations of continuous wave trains that follow classic direct S waves known as coda waves have shown that there are heterogeneities of random size scattered randomly throughout the layers of the classic seismic model This book focuses on recent developments in the area of seismic wave propagation and scattering through the randomly heterogeneous structure of the Earth with emphasis on the lithosphere The presentation combines information from many sources to present a coherent introduction to the theory of scattering in acoustic and elastic materials and includes analyses of observations using the theoretical methods developed **Elastic Wave Field Extrapolation** C.P.A. Wapenaar,2014-04-14 Extrapolation of seismic waves from the

earth s surface to any level in the subsurface plays an essential role in many advanced seismic processing schemes such as migration inverse scattering and redatuming At present these schemes are based on the acoustic wave equation This means not only that S waves shear waves are ignored but also that P waves compressional waves are not handled correctly In the seismic industry there is an important trend towards multi component data acquisition For processing of multi component seismic data ignoring S waves can no longer be justified Wave field extrapolation should therefore be based on the full elastic wave equation In this book the authors review acoustic one way extrapolation of P waves and introduce elastic one way

extrapolation of P and S waves They demonstrate that elastic extrapolation of multi component data decomposed into P and S waves is essentially equivalent to acoustic extrapolation of P waves This has the important practical consequence that elastic processing of multi component seismic data need not be significantly more complicated than acoustic processing of single component seismic data This is demonstrated in the final chapters which deal with the application of wave field extrapolation in the redatuming process of single and multi component seismic data Geophysicists and anyone who is interested in a review of acoustic and elastic wave theory will find this book useful It is also a suitable textbook for graduate students and those following courses in elastic wave field extrapolation as each subject is introduced in a relatively simple manner using the scalar acoustic wave equation In the chapters on elastic wave field extrapolation the formulation whenever possible is analogous to that used in the chapters on acoustic wave field extrapolation The text is illustrated throughout and a bibliography and keyword index are provided

Seismic Waves Masaki Kanao,2012-01-25 The importance of seismic wave research lies not only in our ability to understand and predict earthquakes and tsunamis it also reveals information on the Earth s composition and features in much the same way as it led to the discovery of Mohorovicic s discontinuity As our theoretical understanding of the physics behind seismic waves has grown physical and numerical modeling have greatly advanced and now augment applied seismology for better prediction and engineering practices This has led to some novel applications such as using artificially induced shocks for exploration of the Earth s subsurface and seismic stimulation for increasing the productivity of oil wells This book demonstrates the latest techniques and advances in seismic wave analysis from theoretical approach data acquisition and interpretation to analyses and numerical simulations as well as research applications A review process was conducted in cooperation with sincere support by Drs Hiroshi Takenaka Yoshio Murai Jun Matsushima and Genti Toyokuni

Imaging, Modeling and Assimilation in Seismology Yong-Gang Li,2012-02-22 This work presents current approaches in geophysical research of earthquakes A global authorship from top institutions presents case studies to model measure and monitor earthquakes Among others a full 3D waveform tomography method is introduced as well as propagator methods for modeling and imaging In particular the earthquake prediction method makes this book a must read for researchers in the field

Introduction to Seismology Peter M. Shearer,2019-05-30 This third edition provides a concise yet approachable introduction to seismic theory designed as a first course for graduate students or advanced undergraduate students It clearly explains the fundamental concepts emphasizing intuitive understanding over lengthy derivations and outlines the different types of seismic waves and how they can be used to resolve Earth structure and understand earthquakes New material and updates have been added throughout including ambient noise methods shear wave splitting back projection migration and velocity analysis in reflection seismology earthquake rupture directivity and fault weakening mechanisms A wealth of both reworked and new examples review questions and computer based exercises in MATLAB Python give students the opportunity to apply the techniques they have learned to compute results of interest and

to illustrate Earth's seismic properties. More advanced sections which are not needed to understand the other material are flagged so that instructors or students pressed for time can skip them.

Seismic Wave Propagation in Stratified Media Brian Kennett, 2009-05-01. Seismic Wave Propagation in Stratified Media presents a systematic treatment of the interaction of seismic waves with Earth structure. The theoretical development is physically based and is closely tied to the nature of the seismograms observed across a wide range of distance scales from a few kilometres as in shallow reflection work for geophysical prospecting to many thousands of kilometres for major earthquakes. A unified framework is presented for all classes of seismic phenomena for both body waves and surface waves. Since its first publication in 1983, this book has been an important resource for understanding the way in which seismic waves can be understood in terms of reflection and transmission properties of Earth models and how complete theoretical seismograms can be calculated. The methods allow the development of specific approximations that allow concentration on different seismic arrivals and hence provide a direct tie to seismic observations.

Lithospheric diversity: New perspective on structure, composition and evolution Weijia Sun, Erdinc Saygin, Zengxi Ge, Christian Sippl, Chunquan Yu, Kazunori Yoshizawa, 2023-05-18

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