Physics Of Flow Through Porous Media

Processes of flow and displacement of multiphase fluids through porous media occur in many subsurface systems and have found wide applications in many scientific, technical, and engineering fields. This book focuses on the fundamental theory of fluid flow in porous media, covering fluid flow theory in classical and complex porous media, such as fractured porous media and physicochemical fluid flow theory. Key concepts are introduced concisely and derivations of equations are presented logically. Solutions of some practical problems are given so that the reader can understand how to apply these abstract equations to real world situations. The content has been extended to cover fluid flow in unconventional reservoirs. This book is suitable for senior undergraduate and graduate students as a textbook in petroleum engineering, hydrogeology, groundwater hydrology, soil sciences, and other related engineering fields.

Modeling of flow and transport in groundwater has become an important focus of scientific research in recent years. Most contributions to this subject deal with flow situations, where density and viscosity changes in the fluid are neglected. This restriction may not always be justified. The models presented in the book demonstrate immpressingly that the flow pattern may be completely different when density changes are taken into account. The main applications of the models are: thermal and saline convection, geothermal flow, saltwater intrusion, flow through salt formations etc. This book not only presents basic theory, but the reader can also test his knowledge by applying the included software and can set up own models.

Building on the success of T.J.T. Spanos's previous book The Thermophysics of Porous Media, The Physics of Composite and Porous Media explains non-linear field theory that describes how physical processes occur in the earth. It describes physical processes associated with the interaction of the various phases at the macroscale (the scale at which continuum equations are established) and how these interactions give rise to additional physical processes at the megascale (the scale orders of magnitude larger at which a continuum description may once again be established). Details are also given on how experimental, numerical and theoretical work on this subject fits together. This book will be of interest to graduate students and academic researchers working on understanding the physical process in the earth, in addition to those working in the oil and hydrogeology industries.

Over the past 25 years, the field of VUV physics has undergone significant developments as new powerful spectroscopic tools, VUV lasers, and optical components have become available. This volume is aimed at experimentalists who are in need of choosing the best type of modern instrumentation in this applied field. In particular, it contains a detailed chapter on laboratory sources. This volume provides an up-to-date description of state-of-the-art equipment and techniques, and a broad reference bibliography. It treats phenomena from the standpoint of an experimental physicist, whereby such topics as imaging techniques (NMR, X-ray, ultrasonic, etc.) computer modeling, eletro-kinetic phenomena, diffusion, non-linear wave propagation surface adsorption/desorption, convective mixing, and fracture are specifically addressed.

We study the physics of flow through porous materials in two different ways: by directly visualizing flow through a model three-dimensional (3D) porous medium, and by investigating the deformability of fluid-filled microcapsules having porous shells.

Application of Control Volume Based Finite Element Method (CVFEM) for Nanofluid Flow and Heat Transfer discusses this powerful numerical method that uses the advantages of both finite volume and finite element methods for the simulation of multi-physics problems in complex geometries, along with its applications in heat transfer and nanofluid flow. The book applies these methods to solve various applications of nanofluid in heat transfer enhancement. Topics covered include magnetohydrodynamic flow, electrohydrodynamic flow and heat transfer, melting heat transfer, and nanofluid flow in porous media, all of which are demonstrated with case studies. This is an important research reference that will help readers understand the principles and applications of this novel method for the analysis of nanofluid behavior in a range of external forces. Explains governing equations for nanofluid as working fluid Includes several CVFEM codes for use in nanofluid flow analysis Shows how external forces such as electric fields and magnetic field effects nanofluid flow

This book introduces the reader into the field of the physics of processes occurring in porous media. It targets Master and PhD students who need to gain fundamental understanding the impact of confinement on transport and phase change processes. The book gives brief overviews of topics like thermodynamics, capillarity and fluid mechanics in order to launch the reader smoothly into the realm of porous media. In-depth discussions are given of phase change phenomena in porous media, single phase flow, unsaturated flow and multiphase flow. In order to make the topics concrete the book contains numerous example calculations. Further, as much experimental data as possible is plugged in to give the reader the ability to quantify phenomena.

The book focuses on two issues related to mathematical and numerical modelling of flow in unsaturated porous media. In the first part numerical solution of the governing equations is discussed, with particular emphasis on the spatial discretization of highly nonlinear permeability coefficient. The second part deals with large scale flow in heterogeneous porous media of binary structure. Upscaled models are developed and it is shown that the presence of material heterogeneities may give rise to additional non-equilibrium terms in the governing equations or to hysteresis in the averaged constitutive relationships.

'Turbulence in Porous Media' introduces the reader to the characterisation of turbulent flow, heat and mass transfer in permeable media, including analytical data and a review of available experimental data. Such transport processes occurring a relatively high velocity in permeable media are present in a number of engineering and natural flows. This new edition features a completely updated text including two new chapters exploring Turbulent Combustion and Moving Porous Media. De Lemos has expertly brought together a text that compiles, details, compares and evaluates available methodologies for modelling and simulating flow, providing an essential tour for engineering students working within the field as well as those working in chemistry, physics, applied mathematics, and geological and environmental sciences. Brings together groundbreaking and complex research on turbulence in porous media Extends the original model to situations including reactive systems Now discusses movement of the porous matrix

The Physics of Flow Through Porous MediaThe Physics of Flow Through Porous MediaPhysics of Porous MediaFrontiers Media SAFluids in Porous MediaMorgan & Claypool Publishers

This is the definitive work on the subject by one of the world's foremost hydrologists, designed primarily for advanced undergraduate and graduate students . 335 black-and-white illustrations. Exercises, with answers.

This book offers a fundamental and practical introduction to the use of computational methods. A thorough discussion of practical aspects of the subject is presented in a consistent manner, and the level of treatment is rigorous without being unnecessarily abstract. Each chapter ends with bibliographic information and exercises.

Research into thermal convection in porous media has substantially increased during recent years due to its numerous practical applications. These problems have attracted the attention of industrialists, engineers and scientists from many very diversified disciplines, such as applied mathematics, chemical, civil, environmental, mechanical and nuclear engineering, geothermal physics and food science. Thus, there is a wealth of information now available on convective processes in porous media and it is therefore appropriate and timely to undertake a new critical evaluation of this contemporary information. Transport Phenomena in Porous Media contains 17 chapters and represents the collective work of 27 of the world's leading experts, from 12 countries, in heat transfer in porous media. The recent intensive research in this area has substantially raised the expectations for numerous new practical applications and this makes the book a most timely addition to the existing literature. It includes recent major developments in both the fundamentals and applications, and provides valuable information to researchers dealing with practical problems in thermal convection in porous media. Each chapter of the book describes recent developments in the highly advanced analytical, numerical and experimental techniques which are currently being employed and discussions of possible future developments are provided. Such reviews not only result in the consolidation of the currently available information, but also facilitate the identification of new industrial applications and research topics which merit further work.

This volume contains the lectures presented at the NATO Advanced Study Institute that took place at the University of Delaware, Newark, Delaware, July 18-27, 1982. The purpose of this Institute was to provide an international forum for exchange of ideas and dissemination of knowledge on some selected topics in Mechanics of Fluids in Porous Media. Processes of transport of such extensive quantities as mass of a phase, mass of a component of a phase, momentum and/or heat occur in diversified fields, such as petroleum reservoir engineer ing, groundwater hydraulics, soil mechanics, industrial filtration, water purification, wastewater treatment, soil drainage and irri gation, and geothermal energy production. In all these areas, scientists, engineers and planners make use of mathematical models that describe the relevant transport processes that occur within porous medium domains, and enable the forecasting of the future state of the latter in response to planned activities. The mathe matical models, in turn, are based on the understanding of phenomena, often within the void space, and on theories that re late these phenomena to measurable quantities. Because of the pressing needs in areas of practical interest, such as the develop ment of groundwater resources, the control and abatement of groundwater contamination, underground energy storage and geo thermal energy production, a vast amount of research efforts in all these fields has contributed, especially in the last t~o decades, to our understanding and ability to describe transport phenomena.

The fresh water supplies of the Earth are finite and as the world's population continues to grow humanity's thirst for this water seems unquenchable. Intense pressure is being exerted upon freshwater resources and a lack of adequate clean water is seen as one of the most serious global problems for the 21st century. Indeed it has been said that the next war will be fought over water, not oil. Human health and the health of supporting ecosystems increasingly depends upon our ability to find, control, manage and understand water. In a single volume, The Encyclopedia of Hydrology and Water Resources provides the reader with a comprehensive overview and understanding of the diverse field of hydrology. The intimate inclusion of material on water resources emphasizes the practical applications of this field, applications which are indispensable in any modern approach to the subject. This volume is a vital reference for all hydrologists, hydrogeologists and water engineers worldwide, whether they are concerned with the exploitation of new sources of water, the protection and management of existing reserves, or the science of surface water and groundwater flow. 114 eminent scientists from 17 countries worldwide have contributed to this authoritative volume. Superbly illustrated throughout, it includes almost 300 entries on a range of key topics, including arid and semi-arid zones, climates and climate change, floods and droughts, desertification, entropy, flow measurement, groundwater, hydrological cycle, hydrological models, infiltration, karst hydrology, paleohydrology, precipitation, remote sensing, river pollution prevention, rivers, lakes and seas, satellite hydrology, soil erosion, water treatment, water use, weather radar, and world water balance.

Provides simplified models explaining flows in heterogeneous rocks, their physics and energy-production processes, for researchers, energy-industry professionals and graduate students.

In this standard reference of the field, theoretical and experimental approaches to flow, hydrodynamic dispersion, and miscible displacements in porous media and fractured rock are considered. Two different approaches are discussed and contrasted with each other. The first approach is based on the classical equations of flow and transport, called 'continuum models'. The second approach is based on modern methods of statistical physics of disordered media; that is, on 'discrete models', which have become increasingly popular over the past 15 years. The book is unique in its scope, since (1) there is currently no book that compares the two approaches, and covers all important aspects of porous media problems; and (2) includes discussion of fractured rocks, which so far has been treated as a separate subject. Portions of the book would be suitable for an advanced undergraduate course. The book will be ideal for graduate courses on the subject, and can be used by chemical, petroleum, civil, environmental engineers, and geologists, as well as physicists, applied physicist and allied scientists that deal with various porous media problems.

This book provides a fundamental description of multiphase fluid flow through porous rock, based on understanding movement at the pore, or microscopic, scale.

Studies of fluid flow and heat transfer in a porous medium have been the subject of continuous interest for the past several decades because of the wide range of applications, such as geothermal systems, drying technologies, production of thermal isolators, control of pollutant spread in groundwater, insulation of buildings, solar power collectors, design of nuclear reactors, and compact heat exchangers, etc. There are several models for simulating porous media such as the Darcy model, Non-Darcy model, and non-equilibrium model. In porous media applications, such as the environmental impact of buried nuclear heat-generating waste, chemical reactors, thermal energy transport/storage systems, the cooling of electronic devices, etc., a temperature discrepancy between the solid matrix and the saturating fluid has been observed and recognized.

Fluid and flow problems in porous media have attracted the attention of industrialists, engineers and scientists from varying disciplines, such as chemical, environmental, and mechanical engineering, geothermal physics and food science. There has been a increasing interest in heat and fluid flows through porous media, making this book a timely and appropriate resource. Each chapter is systematically detailed to be easily grasped by a research worker with basic knowledge of fluid mechanics, heat transfer and computational and experimental methods. At the same time, the readers will be informed of the most recent research literature in the field, giving it dual usage as both a post-grad text book and professional reference. Written by the recent directors of the NATO Advanced Study Institute session on 'Emerging Technologies and Techniques in Porous Media' (June 2003), this book is a timely and essential reference for scientists and engineers within a variety of fields.

Multiphase Fluid Flow in Porous and Fractured Reservoirs discusses the process of modeling fluid flow in petroleum and natural gas reservoirs, a practice that has become increasingly complex thanks to multiple fractures in horizontal drilling and the discovery of more unconventional reservoirs and resources. The book updates the reservoir engineer of today with the latest developments in reservoir simulation by combining a powerhouse of theory, analytical, and numerical methods to create stronger verification and validation modeling methods, ultimately improving recovery in stagnant and complex reservoirs. Going beyond the standard topics in past literature, coverage includes well treatment, Non-Newtonian fluids and rheological models, multiphase fluid coupled with geomechanics in reservoirs, and modeling applications for unconventional petroleum resources. The book equips today's reservoir engineer and modeler with the most relevant tools and knowledge to establish and solidify stronger oil and gas recovery. Delivers updates on recent developments in reservoir simulation such as modeling approaches for multiphase flow simulation of fractured media and unconventional reservoirs Explains analytical solutions and approaches as well as applications to modeling verification for today's reservoir problems, such as evaluating saturation and pressure profiles and recovery factors or displacement efficiency Utilize practical codes and programs featured from online companion website

The need to predict, understand, and optimize complex physical and c- mical processes occurring in and around the earth, such as groundwater c- tamination, oil reservoir production, discovering new oil reserves, and ocean hydrodynamics, has been increasingly recognized. Despite their seemingly disparate natures, these geoscience problems have many common mathe- tical and computational characteristics. The techniques used to describe and study them are applicable across a broad range of areas. The study of the above problems through physical experiments, mat- matical theory, and computational techniques requires interdisciplinary col- boration between engineers, mathematicians, computational scientists, and other researchers working in industry, government laboratories, and univ- sities. By bringing together such researchers, meaningful progress can be made in predicting, understanding, and optimizing physical and chemical processes. The International Workshop on Fluid Flow and Transport in Porous - dia was successfully held in Beijing, China, August 2{6, 1999. The aim of this workshop was to bring together applied mathematicians, computational scientists, and engineers working actively in the mathematical and nume- cal treatment of ?uid ?ow and transport in porous media. A broad range of researchers presented papers and discussed both problems and current, state-of-the-art techniques.

This is the definitive work on the subject by one of the world's foremost hydrologists, designed primarily for advanced undergraduate and graduate students. 335 black-and-white illustrations. Exercises, with answers.

This book presents and discusses the construction of mathematical models that describe phenomena of flow and transport in porous media as encountered in civil and environmental engineering, petroleum and agricultural engineering, as well as chemical and geothermal engineering. The phenomena of transport of extensive quantities, like mass of fluid phases, mass of chemical species dissolved in fluid phases, momentum and energy of the solid matrix and of fluid phases occupying the void space of porous medium domains are encountered in all these disciplines. The book, which can also serve as a text for courses on modeling in these disciplines, starts from first principles and focuses on the construction of well-posed mathematical models that describe all these transport phenomena.

The study of multiphase flow through porous media is undergoing intense development, mostly due to the recent introduction of new methods. After the profound changes induced by percolation in the eighties, attention is nowadays focused on the pore scale. The physical situation is complex and only recently have tools become available that allow significant progress to be made in the area. This volume on Multiphase Flow in Porous Media, which is also being published as a special issue of the journal Transport in Porous Media, contains contributions on the lattice-Boltzmann technique, the renormalization technique, and semi-phenomenological studies at the pore level. Attention is mostly focused on two- and three-phase flows. These techniques are of tremendous importance for the numerous applications of multiphase flows in oil fields, unsaturated soils, the chemical industry, and environmental sciences.

This book examines the relationship between transport properties and pore structure of porous material. Models of pore structure are presented with a discussion of how such models can be used to predict the transport properties of porous media. Portions of the book are devoted to interpretations of experimental results in this area and directions for future research. Practical applications are given where applicable, and are expected to be useful for a large number of different fields, including reservoir engineering, geology, hydrogeology, soil science, chemical process engineering, biomedical engineering, fuel technology, hydrometallurgy, nuclear reactor technology, and materials science. Presents mechanisms of immiscible and miscible displacement (hydrodynamic dispersion) process in porous media Examines relationships between pore structure and fluid transport Considers approaches to enhanced oil recovery Explores network modeling and perolation theory

Porous and Complex Flow Structures in Modern Technologies represents a new approach to the field, considering the fundamentals of porous media in terms of the key roles played by these materials in modern technology. Intended as a text for advanced undergraduates and as a reference for practicing engineers, the book uses the physics of flows in porous materials to tie together a wide variety of important issues from such fields as biomedical engineering, energy conversion, civil engineering, electronics, chemical engineering, and environmental engineering. Thus, for example, flows of water and oil through porous ground play a central role in energy exploration and recovery (oil wells, geothermal fluids), energy conversion (effluents from refineries and power plants), and environmental engineering (leachates from waste repositories). Similarly, the demands of miniaturization in electronics and in biomedical applications are driving research into the flow of heat and fluids through small-scale porous media (heat exchangers, filters, gas exchangers). Filters, catalytic converters, the drying of stored grains, and a myriad of other applications involve flows through porous media. By providing a unified theoretical framework that includes not only the traditional homogeneous and isotropic media but also models in which the assumptions of representative elemental volumes or global thermal equilibrium fail, the book provides practicing engineers the tools they need to analyze complex situations that arise in practice. This volume includes examples, solved problems and an extensive glossary of symbols.

This monograph presents, for the first time, a unified and comprehensive introduction to some of the basic transport properties of porous media, such as electrical and hydraulic conductivity, air permeability and diffusion. The approach is based on critical path analysis and the scaling of transport properties, which are individually described as functions of saturation. At the same time, the book supplies a tutorial on percolation theory for hydrologists, providing them with the tools for solving actual problems. In turn, a separate chapter serves to introduce physicists to some of the language and complications of groundwater hydrology necessary for successful modeling. The end-of-chapter problems often indicate open questions, which young researchers entering the field can readily start working on. This significantly revised and expanded third edition includes in particular two new chapters: one on advanced fractal-based models, and one devoted to the discussion of various open issues such as the role of diffusion vs. advection, preferential flow vs. critical path, universal vs. non-universal exponents for conduction, and last but not least, the overall influence of the experimental apparatus in data collection and theory validation. "The book is suitable for advanced graduate courses, with selected problems and questions appearing at the end of each chapter. [...] I think the book is an important work that will guide soil scientists, hydrologists, and physicists to gain a better qualitative and quantitative understanding of multitransport properties of soils." (Marcel G. Schaap, Soil Science Society of America Journal, May-June, 2006)

This text forms part of material taught during a course in advanced reservoir simulation at Delft University of Technology over the past 10 years. The contents have also been presented at various short courses for industrial and academic researchers interested in background knowledge needed to perform research in the area of closed-loop reservoir management, also known as smart fields, related to e.g. model-based production optimization, data assimilation (or history matching), model reduction, or upscaling techniques. Each of these topics has connections to system-theoretical concepts. The introductory part of the course, i.e. the systems description of flow through porous media, forms the topic of this brief monograph. The main objective is to present the classic reservoir simulation equations in a notation that facilitates the use of concepts from the systems-and-control literature. Although the theory is limited to the relatively simple situation of horizontal two-phase (oil-water) flow, it covers several typical aspects of porous-media flow. The first chapter gives a brief review of the basic equations to represent single-phase and two-phase flow. It discusses the governing partial-differential equations, their physical interpretation, spatial discretization with finite differences, and the treatment of wells. It contains well-known theory and is primarily meant to form a basis for the next chapter where the equations will be reformulated in terms of systems-and-control notation. The second chapter develops representations in state-space notation of the porous-media flow equations. The systematic use of matrix partitioning to describe the different types of inputs leads to a description in terms of nonlinear ordinary-differential and algebraic equations with (state-dependent) system, input, output and direct-throughput matrices. Other topics include generalized state-space representations, linearization, elimination of prescribed pressures, the tracing of stream lines, lift tables, computational aspects, and the derivation of an energy balance for porous-media flow. The third chapter first treats the analytical solution of linear systems of ordinary differential equations for single-phase flow. Next it moves on to the numerical solution of the two-phase flow equations, covering various aspects like implicit, explicit or mixed (IMPES) time discretizations and associated stability issues, Newton-Raphson iteration, streamline simulation, automatic time-stepping, and other computational aspects. The chapter concludes with simple numerical examples to illustrate these and other aspects such as mobility effects, well-constraint switching, time-stepping statistics, and system-energy accounting. The contents of this brief should be of value to students and researchers interested in the application of systems-and-control concepts to oil and gas reservoir simulation and other applications of subsurface flow simulation such as CO2 storage, geothermal energy, or groundwater remediation.