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Introduction

The flow of fluids in porous media is of great technological importance. Clearly the flow of groundwater or of oil, gas and water in reservoirs has a very significant economical aspect.

The information about flows in porous media is spread over many fields of science and technology. For instance, in biochemistry and microbiology the separation of macromolecules on packed columns of "chromatographic" materials is a standard technique. The separation of pieces of DNA by electrophoresis in gel layers is a common analytical and preparative method in biotechnology. The understanding of how these methods work in scientific terms is, however, rather limited.

In this book we will try to learn about various physical aspects of flows in porous media. The properties of porous media is a part of condensed matter physics. Indeed, much of the current effort in solid state physics and in statistical physics concentrates on the properties of disordered systems, fluctuations, *phase-transitions* and *percolation*. Associated problems include the precipitation and clustering phenomena that may occur both in bulk fluids and in fluids in porous media. Other areas of relevant active scientific inquiry include fuel cell technologies, polymer and colloidal chemistry and physics, interfacial phenomena, and the adsorbtion of molecules on interfaces and solids. Also, most biological systems involve flow through porous media in some way. This is exemplified by the blood capillaries in a human hand or the flow of air through the nose of a reindeer.

As a guiding principle we will try to make the connection between the microscopic and the macroscopic aspects of porous media.

Also, we will proceed from the simple to the more complex, starting with basic geometric concepts and basic hydrodynamics. Then we proceed to use this pore-scale description to derive a description that pertains to larger scales, like Darcy's law, before we introduce fluids that mix or create interfaces with surface tension between them.

https://doi.org/10.1017/9781009100717.002 Published online by Cambridge University Press

We will study the flow of fluids through capillaries, also with droplets or other phases present. Capillary pressure, wetting and interfacial tension are important for the multiphase flow in porous media. Also because of the large specific surface area of porous media, the surface adsorbtion of molecules is of great interest and will be discussed in some detail.

Later we will discuss the percolation problem. In particular we will discuss the statistical, structural and transport properties of percolating systems. This will include a discussion of critical behavior and the scaling properties of various physical quantities.

The simultaneous flow of several fluids in porous media will be discussed in detail, and we will demonstrate both immiscible and miscible flow and describe the types of pattern they give rise to. Toward the end we turn to numerical simulations of multiphase flow. These simulations too are based on the *bottom-up* apporach, that is, the idea that macroscopic processes and their description should be based on the underlying processes at the micro level. The lattice gas and lattice Boltzmann models that we introduce to simulate the fluid flow equations are based on a particle picture of the fluids, and it is shown how their behavior links to the hydrodynamic behavior at the larger scale.