Preface

The physical description of our environment consists of relating various essential quantities by laws of nature, quantities identified by observation, experiment and a posteriori verification. One common difficulty is to relate the properties of a system observed at a particular scale to those at a larger or smaller scale. In general, we separate the scales by averaging the values at the smaller scales and treating as constant the values varying on larger scales. Such descriptions are not always valid, for example in situations where multiple physical scales play a role. Here we describe new approaches specially adapted to such situations, taking changes of states of matter as the first problems we tackle. Today we know of a wide variety of critical systems in nature. The aim of this book is to unearth the common characteristics of these phenomena. The central concept of coherence length (or time) enables us to characterise critical phenomena by the size (or duration) of fluctuations. The first examples treated are spatial critical phenomena, with their associated divergence of the coherence length, second-order phase transitions, and percolation transition. After that we describe temporal critical phenomena, or even spatiotemporal, with their associated appearance of chaos.

The new challenge is that the description of these phenomena without characteristic length/time scales should be global, affecting all scales simultaneously, and should strive to understand their mutual organisation. More precisely the way in which different length/time scales are coupled to each other becomes determinate. The key concepts of *scale invariance* and *universality* are introduced. The emergence of these ideas was a turning point in modern physics and has revolutionised the study of certain physical phenomena. Analyses of characteristics at one particular scale has given way to investigations of *mechanisms of coupling between different scales*. One essential tool, renormalisation, enables this analysis; it establishes the scaling laws, demonstrates the universal physical behaviour within a Universality class and the insensitivity to microscopic details. Universality emerges as a crucial property in which it legitimises the use of basic models. A model reduced to just the essential elements is enough to describe the common characteristics of all the systems of a universality class. Examples considered in this book include the famous Ising model, percolation, logistic maps, etc.

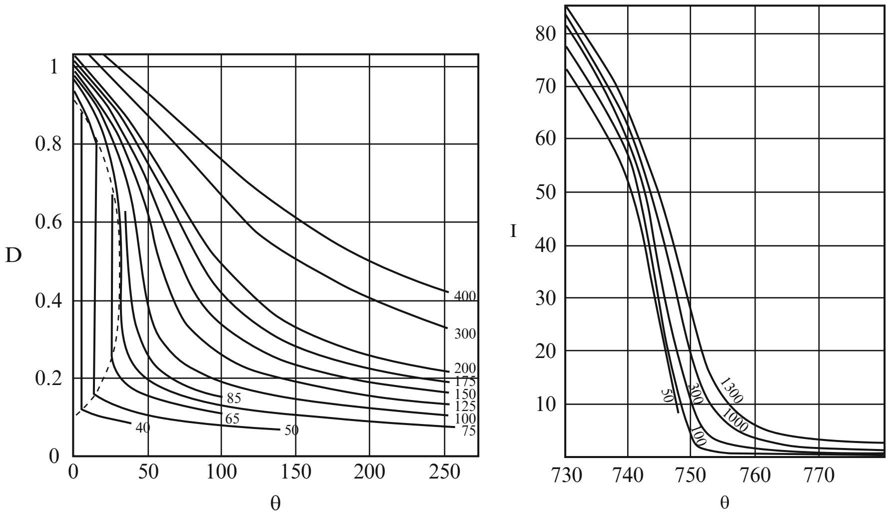

Fig. 1 Analogy, proposed by Pierre Curie as a conclusion of his PhD thesis (1895), between the density of a fluid (*left*) and the magnetization of a material (*right*), both as a function of temperature, and respectively as a function of pressure and magnetic field (for further details, see text)

To conclude this introduction, it is fitting to give tribute to Pierre Curie, who had this remarkable intuition during his work for his Ph.D. thesis in 1895, writing: "There are analogies between the function $f(I, H, T) = 0$ related to a magnetic object (Fig. 1 *right*) and the function $f(D, p, T) = 0$ related to a fluid (Fig. 1 *left*). The intensity of magnetization I corresponds to the density D, the intensity of the magnetic field H corresponds to the pressure p and the absolute temperature T plays the same role in both cases. [...]. The way in which the magnetization varies as a function of temperature close to the transition temperature, the magnetic field remaining constant, is reminiscent of the way in which the density of a fluid varies as a function of temperature near the critical temperature (while the pressure remains constant). The analogy extends to the curves $I = \varphi(T)$ that we have obtained and the curves $D = \varphi(T)$ corresponding to critical pressures. The left hand figure below, established with the experimental data from M. Amagat on carbonic acid and the right hand figure below, established with my experiments on iron, shows the idea of this analogy."

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