Foreword

Scale-up engineering is an extremely effective tool for engineers of all disciplines. It is based on the description of technical objects by complete sets of dimensionless numbers. The scale-up laws are very helpful in solving engineering problems by simple or small-scale experiments. Thus, dimensionless numbers and scale-up laws are used in many fields of natural and engineering sciences. Classic fields of applications are fluid mechanics, heat and mass transfer, mechanics (statics, dynamics, stress and strain), and aeronautics. Novel fields of applications are reaction engineering, acoustics, and space sciences.

The basis for the effectiveness of dimensionless numbers is the fact that fundamental physical laws are used in the definition of the units (dimensions) of physical quantities. For instance, the unit of force ($N = kg \cdot m/s^2$) reflects the second law of Newton, force = mass times acceleration. Analogously, the unit of electrical resistance ($R = V/A$) stems from Ohm's law, voltage = resistance times intensity of current. Thus, the units reflect elementary physical laws. The formulation of physical relationships by dimensionless numbers uses (mostly unconsciously) the relevant fundamental physical laws. This fact explains the enlarged range of validity of a single data point when presented with a complete set of dimensionless numbers. Such presentations include not only the experimental results but also the relevant physical laws in a rudimentary form.

The book is divided into five Chapters. Chapter 1 deals with the fundamentals of formulating physical relationships. In this Chapter, it is explained why and how physical laws are used for the definition of the units of physical quantities.

The Chapter 2 explains the structure of dimensionless numbers and presents methods for the systematic derivation of such numbers. A very elegant and systematic method developed by Pawlowski /0.12, 1.1/ for calculating dimensionless numbers using the knowledge of the relevant quantities is presented. In this Chapter, it is demonstrated that only complete sets of dimensionless numbers facilitate the solution of technical problems. Single dimensionless numbers and their interpretation are of little or no help. It is demonstrated that a large number of different sets of dimensionless numbers exists for each problem, which indeed allows a rigorous description. However, only a few of them are favorably applied to solving a given problem.

Chapter 3 demonstrates procedures for the application of dimensionless numbers to the investigation of physical phenomena. Of primary interest is which of the different sets of dimensionless numbers offers the greatest advantages. In this context, the often used physical interpretation of single dimensionless numbers is questioned.

Chapters 4 and 5 deal with the development of the principles of similarity (scale-up models) from a knowledge of complete sets of dimensionless numbers. The scale-up laws allow the investigation of an unknown phenomenon by simple models instead of by a complex and expensive prototype. Because of the degree of freedom inherent to the laws of similarity, the model can be much simpler than the prototype. The constraints for developing simple model experiments are presented in detail. They refer to both the number and the type of free quantities. Since these constraints often prevent simple model experiments with total similarity, strategies for dealing with partial similarity are presented in Chapter 5.

In all Chapters of the book, the text is accompanied by a large number of thoroughly elaborated examples. These examples are arranged in boxes in order to not hinder the easy readability of the text. Only the principal procedures and the most essential results are explained in the text. All the details are contained in the boxes. In total, 65 examples from all disciplines of engineering sciences are presented in the book.