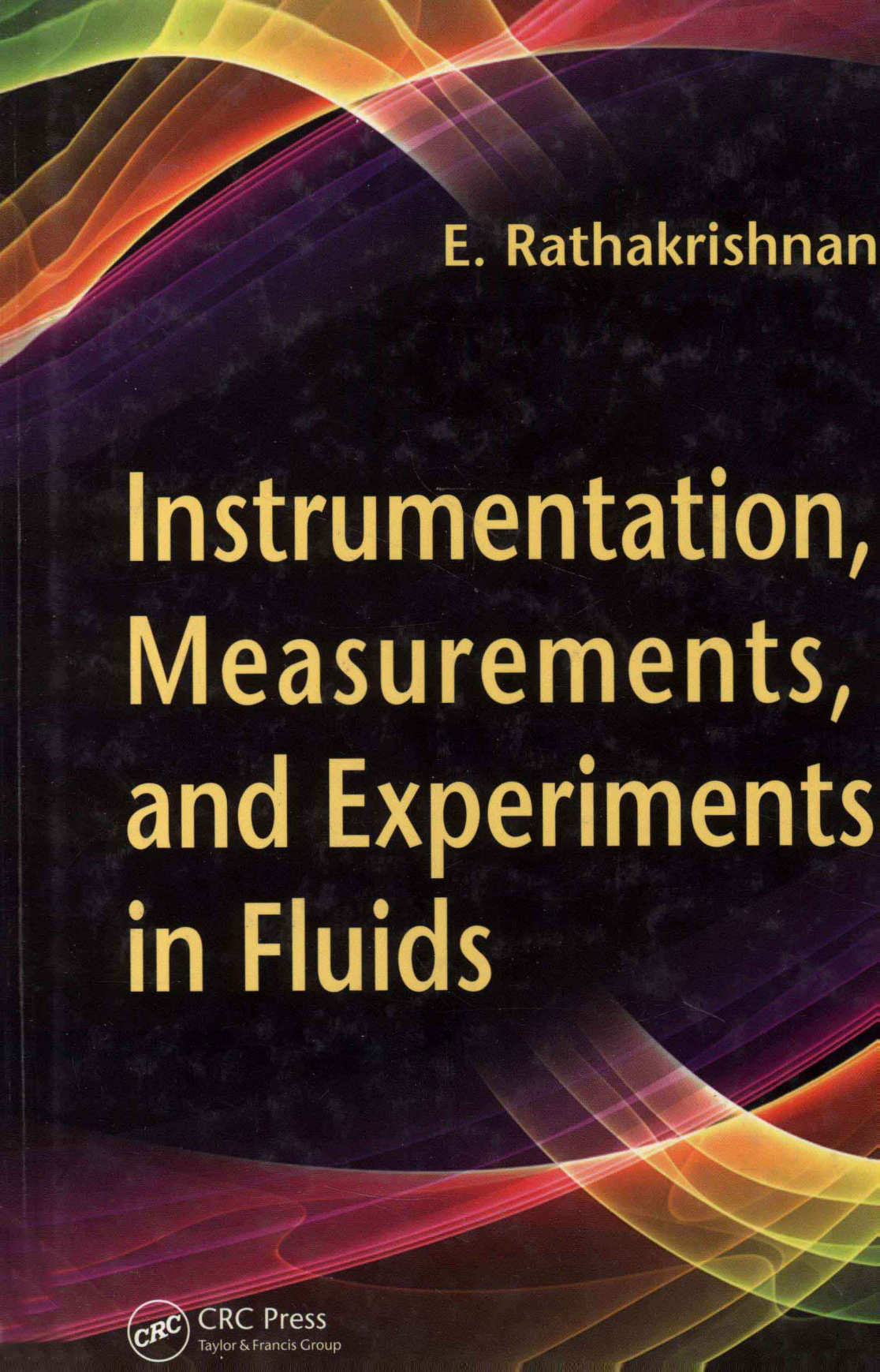




E. Rathakrishnan

Instrumentation, Measurements, and Experiments in Fluids



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Instrumentation, Measurements, and Experiments in Fluids

Dedication

*This book is dedicated to my parents,
Mr. Thammanur Shunmugam Ethirajan
and
Mrs. Aandaal Ethirajan*

E. Rathakrishnan

Preface

This book was developed to serve as the text for a course on experiments in fluids at the introductory level for an undergraduate course and for an advanced level course at the graduate level. The fundamentals of the measuring principles are covered as they are treated at the undergraduate level. The book begins with the most elementary ideas of flow parameters such as pressure and temperature and develops the measuring principles and their limitations and features influencing them.

To meet the requirements of many university syllabi, a chapter reviewing the principles of fluid dynamics is included. The treatment of the material is such as to emphasize the working principle associated with the various measuring instruments. The entire spectrum of instruments used for experiments with fluid flows is addressed in this book, with necessary explanations on every aspect. The material covered in this book is so designed that any beginner can follow it comfortably. The topics covered are broad-based, starting from the basic principles on which an instrument works and progressing toward the physics of the flow that governs the functional aspect of the instrument. Some features presented are new and were generated by the research and interpretation of the author.

The book is organized in a logical manner and the topics are discussed in a systematic way. First, the need and objective of experimental science and the physics of fluid flow processes are reviewed in order to establish a firm basis for the experimental scheme and the associated instruments and their operating principles. Following this, the primary devices in the field of experimental fluid and gas dynamics, namely the wind tunnels are introduced. Starting from the basic principles, the design, operation, and application procedures of subsonic and supersonic tunnels are discussed in detail. Also, an outline of hypersonic and high enthalpy facilities is presented to get an overall picture of such equipment. Flow visualization methods for low-speed and high-speed flows are presented with appropriate illustrations. An extensive coverage of the hot-wire anemometer is given, covering the operating and application procedure and highlighting the advantages and disadvantages. Some of the popular analogy methods used for fluid flow studies at different flow regimes are augmented with illustrations. The pressure measurements chapter gives an extensive coverage of many practical devices, their working principles, application details, and limitations. A brief introduction of the laser Doppler anemometer is given, highlighting its working principle and

specific advantages. Various temperature-measuring devices are presented with an extensive coverage of thermocouples. An introduction to measurement of shear stress presents some of the techniques specially developed for this purpose. Mass and volume flow measurement techniques are covered systematically. Some special flows and equipment to develop them are presented briefly. To get an idea about the data acquisition and processing, a brief introduction of the acquisition procedure and various components and their functional details of personal computers are presented. Finally, the basic features of uncertainty, its definition, and calculation procedure are discussed. A brief summary is included at the end of each chapter for quickly recapturing the material discussed.

This book is the outgrowth of lectures presented over a number of years, both at the undergraduate and graduate levels. The student, or reader, is assumed to have a background in the basic courses of fluid mechanics and a course on gas dynamics. Advanced undergraduate students should be able to handle the subject material comfortably. Sufficient details have been included that the text can be used for self-study. Thus, the book can be useful for scientists and engineers working in the fields of experimental fluid mechanics and gas dynamics in industries and research laboratories.

I wish to thank my colleagues who reviewed this text during the course of its development and, in particular, Professor S. Elangovan, Department of Aerospace Engineering, Madras Institute of Technology, Anna University, Chennai, India, who urged me to write this book and helped me in checking the manuscript at various stages of its development. My sincere thanks to my undergraduate and graduate students at the Indian Institute of Technology Kanpur, who are directly and indirectly responsible for the development of this book. My special thanks to my doctoral students Ignatius John, S. Elangovan, Himanshu Agrawal, K. Srinivasan, Shashi Bhushan Verma, Krishna Murari Pandey, Sher Afgan Khan, Shibu Clement, P. Jeyajothi Raj, G. Balu, V. Thiagarajan, Shiva Prasad, P. Lovaraju, B.R. Vinoth, R. Kalimuthu, Dananjaya Rao, K.L. Narayana, Senthil Kumar, and V.N. Sukumar for their help during course of development of this book. My appreciation to my graduate student Manoj Kumar for typing the manuscript and S. Saravanan, Gaurav Garg, K. Ramesh, Atul Rathore, R. Srikanth, Murali Rajan, M.S. Khalid, R.B. Sreejith, Mrinal Kaushik, Jayant Vishnu, K. Sreejith, Amit Kumar, Vijay Agrawal, Mohana Murali, and S. Jayaprakash for checking the manuscript. My special appreciation to my trainee student, Sunil Kumar Dwivedi, for critically checking the manuscript and giving some useful suggestions. I sincerely thank my doctoral student Shibu Clement for setting all the figures for this book in figtex. My appreciation to Yoshiki Takama, doctoral student of the Department of Advanced Energy, University of Tokyo, for his spontaneous help during various stages of the finalization of this book.

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E. Rathakrishnan

About the Book

Instrumentation, Measurements, and Experiments in Fluids is the ideal text or reference for students and professionals interested in specializing in this field. Written by an internationally recognized authority on the subject, it features an elegant, to the point writing style along with sufficient depth and clarity for self-study. This book provides an in-depth insight to all the vital topics and issues associated with the devices and instruments used for fluid mechanics and gas dynamics experiments. Some of the unique features of this book are the following.

- A concise coverage of wind tunnels
- Extensive treatment of the principles on which the pressure- and temperature-measuring instruments work and their limitations
- A unique, to the point coverage of hot-wire anemometers
- Exhaustive treatment of flow visualization techniques
- An in-depth presentation of analogue methods
- An introduction to uncertainty analysis

About the Author

Ethirajan Rathakrishnan is Professor of Aerospace Engineering at Indian Institute of Technology Kanpur, India. He is well known internationally for his research in the area of high-speed jets. He has published several research articles in many reputed international journals. A Fellow of the Royal Aeronautical Society, Professor Rathakrishnan serves as Regional Editor of *Journal of Visualization*. He has authored four books: *Gas Dynamics* (Prentice-Hall of India, 1995), *Fundamentals of Engineering Thermodynamics*, 2nd ed. (Prentice-Hall of India, 2005), *Fluid Mechanics: An Introduction*, 2nd ed. (Prentice-Hall of India, 2007), and *Gas Tables*, 2nd ed. (Universities Press, India, 2004).

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