

Preface

Black-body radiation is a well-studied area in modern physics. The thermal radiative and thermodynamic properties of black bodies were extensively studied theoretically in the past. As a result, the temperature dependences of the total radiation power per unit area, total energy density, number density of photons, Helmholtz free energy density, entropy density, and others are described by well-known equations. It is essential to note that these properties of black-body radiation were investigated in the semi-infinite range of the electromagnetic spectrum.

However, in practically all devices or instruments that deal with thermal radiation (detectors, receivers, incandescent sources of light, etc.), only a small region of the electromagnetic spectrum is used. Therefore, when designing these devices the knowledge of the black-body thermal radiative and thermodynamic properties in a finite spectral range is necessary.

Over the years we, the authors, have been closely involved with the study of this phenomenon. This book accumulates our own results obtained in this area. The main purpose of this book is to present the calculated values for the black-body radiative, thermodynamic, and chromatic functions in the various finite spectral ranges at different temperatures in the form of tables.

The book conceptually consists of two major parts. The first part (Chaps. 1–5) describes the analytical formulas and methods used for the calculation of the numerous black-body functions. The second part (Chap. 6) of the book presents the tables with the obtained numerical results.

The tables presented in this book are primarily meant to be used by engineers, scientists, researchers, lecturers, university and college students, and others who are interested in the black-body functions in a finite spectral range.

In Chap. 1, the exact analytical expressions for the thermal radiative functions, such as the total radiation power per unit area, total energy density, and number density of photons, are presented.

Chapter 2 is devoted to obtaining exact analytical expressions for the thermodynamic functions in the finite spectral range. These functions are (a) Helmholtz free energy density, (b) enthalpy density, (c) entropy density, (d) heat capacity at

constant volume, and (e) pressure. Black-body radiative and thermodynamic functions for different domains are discussed. Tables 6.1–6.3 are calculated using the exact analytical expressions for the thermal radiative and thermodynamic functions of black-body radiation in the various finite spectral ranges at different temperatures. We performed the calculations over a very wide range of temperatures (up to 1 K), considering the possible applications in astrophysics, for example, those which use the FIRAS instrument data.

In Chap. 3, we present examples of the use of Tables 6.1–6.3 for different measurement devices. Special attention is given to the calculation of the thermal radiative and thermodynamic functions of Cosmic Microwave Background (CMB) radiation.

The chromatic functions of black-body radiation, such as the chromaticity coordinates and R (red), G (green), and B (blue) values, are investigated in Chap. 4. In Tables 6.5–6.14, the temperature dependence of the linear and nonlinear RGB values for different color spaces (Rec.709 (HDTV), sRGB, and Adobe RGB) is presented. In Chap. 5, a number of optimization problems are formulated for various thermal black-body radiative and thermodynamic functions in a finite range of frequencies. A new generic approach for solving these optimization problems is proposed. The universal numerical results for the solutions of these optimization problems are obtained. In Chap. 6, the tables of black-body radiative, thermodynamic, and chromatic functions in the various finite spectral ranges at different temperatures are presented.

The derivations of the formulas for the total energy density and Helmholtz free energy density in a given spectral range are provided in Appendices.

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Functions: Tables in Finite Spectral Ranges

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