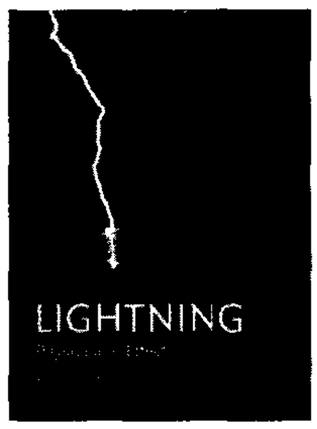
LIGHTNING: PHYSICS AND EFFECTS

Vladimir A. Rakov and Martin A. Uman, 2003, 698 pp., $200.00, hardbound, Cambridge University Press, ISBN 0-521-58327-6

Lightning is clearly among the nation's worst weather hazards, and in recent years, scientists and engineers have made considerable progress in measuring the physical characteristics of lightning, and in understanding its effects on ground-based and airborne systems. The authors of this book, Vladimir A. Rakov and Martin A. Uman, have more than 70 years of experience in lightning research, and are responsible for much of this progress. Together, they have authored or coauthored more than 300 scientific and technical papers, many of them jointly, and here they have attempted to present all that is known about lightning and its effects in a single volume.

Chapter 1 begins with a brief review of the history of the subject and the terminology that is used to describe cloud-to-ground (CG) discharges, and it concludes with a summary of the characteristics of negative CG flashes and the global electric circuit. Chapter 2 reviews the frequencies and types of discharges and the area densities of flashes that have been inferred from thunder statistics, lightning locating systems, and satellite measurements. It also shows how to use the measured area densities to estimate the frequency of strikes to buildings and tall towers. Chapter 3 describes the electrical structure of air mass thunderstorms and larger storm systems, and the mechanisms of cloud electrification on small and large spatial scales. Chapter 4, the largest and probably the most important chapter in the book, gives a detailed description of the luminous and electrical characteristics of the most common type of CG lightning—negative flashes initiated by a downward-propagating leader that contain one or more return strokes. Chapters 5–8 discuss positive and bipolar flashes to ground, upward lightning initiated by ground-based objects, the artificial initiation (or triggering) of lightning by ground-based activity (especially rockets trailing grounded and ungrounded wires), and winter lightning in Japan, respectively. Chapter 9 describes the electric field and radio-frequency (RF) signatures produced by cloud discharges, and chapter 10 discusses the frequency and characteristics of lightning strikes to aircraft. Chapter 11 reviews the causes and characteristics of thunder, and chapter 12 summarizes models of return strokes, stepped- and dart-leaders, and M-components, and the ways of describing the electromagnetic fields produced by these processes. Chapter 13 discusses "atmospherics" (i.e., the radio signals produced by distant lightning), the propagation of these signals in the Earth–ionosphere cavity, Schumann resonances, and whistlers. Chapter 14 reviews the effects of lightning on the middle and upper atmosphere and the properties of transient luminous events, such as red sprites, elves, and blue jets. Chapter 15 describes the production of nonequilibrium trace gases (e.g., NO and NO_x) by lightning and the relative importance of lightning as a source of these gases on a global scale. Chapter 16 reviews what is known about the characteristics of extraterrestrial lightning, and chapter 17 describes the principles of operation of most ground-based and satellite lightning-detection systems. Chapter 18 reviews the mechanisms of lightning damage, the basic elements of lightning protection, and lightning test standards, and chapter 19 describes lightning safety and the hazards that lightning presents to humans. The book concludes with a discussion of ball lightning and other unusual discharges in chapter 20. There is an excellent subject index, and a list of previous books about lightning and related subjects is given in an appendix. Nine color plates of selected figures have been inserted in chapter 12 between pages 406 and 407.



In the preface, Rakov and Uman state that their goal in writing this book was to "present a balanced review of the present knowledge of lightning phys-

ics and lightning effects," and they have certainly achieved that goal. All of the important lightning parameters are described in considerable detail, and the text includes 288 figures and 71 tables (many with multiple parts). There are over 6000 references to the scientific and technical literature (up to the spring of 2002), listed alphabetically by first author at the end of each chapter, but not all of these citations are discussed in the chapter after which they are listed (see below). The chapter bibliographies include many references to literature in Russia and Eastern Europe that have not been cited previously in the West. One could question how the authors have arranged the subject matter within and between chapters, and/or whether some chapters could be merged into one, but on the whole, the sequence of topics is logical and easy to follow. Chapters 4–10 and 12–14 are suitable for a graduate textbook in a course on lightning physics and effects.

My only criticisms of the book are minor. The last eight chapters are rather uneven in their breadth and depth, and some of the material in the early chapters is repeated in the later chapters with the same references. Figure 1.3 shows how the electrical conductivity of the atmosphere increases almost exponentially with altitude, but the effects of this increase have been ignored without comment in Figure 3.2 (see, for example, Holzer and Saxon 1952; Kasemir 1959; and Hays and Roble 1979). Chapter 4, on negative CG been split into three sections, with some duplication between sections, so one needs to be careful when searching for specific references in this chapter. Chapter 2 references—but does not discuss—some interesting work by Finke (1999) on the spatial and temporal coherence of CG flashes, and chapter 5 references—but does not discuss—an important experiment by Willett et al. (1999) that measured the electric fields aloft (and the associated potential differences), in which positive leaders were initiated and then developed into rocket-triggered flashes at Camp Blanding. The appendix of books about lightning and related phenomena could have included Symons (1882) and Fleming (1939) (both of which also contain excellent bibliographies), Lodge (1892), Mathias (1924), and the beautifully illustrated book by Hermant (2002). The citations to Gunn (1953) and Pierce and Wormell (1953) in the appendix are not books, but individual chapters in Byers (1953). There are relatively few typographical errors for a book of this length, and the authors maintain a list of those at http://plaza.ufl.edu/rakov/LPE/Errata.doc.

This book is clearly the most complete compilation of material on the physics and effects of lightning that exists today. It is well written, and I expect that it will be an important reference for both specialists and nonspecialists alike in future years. The only real problem, if indeed there is one, is that rate of progress flashes, is rather long (105 pages) relative to chapters 8 and 19 (12 and 13 pages, respectively), so in future editions, it might be worthwhile to consider moving the material on modeling the electromagnetic fields that is currently in chapter 4 (sections 4.4 and 4.6) to chapter 12, where it could be treated more thoroughly. It would also be good to add an appendix that derives equations 4.10 and 4.11 and explains the retardation effects that are alluded to in section 4.6.4. Physicists might like to see more details on ion chemistry and the phenomenology of high voltage breakdown than is given in chapter 4, and electrical engineers might like to have more material on the direct and indirect effects of lightning on power and communication systems, and the ways of protecting these systems, than is given in chapter 18. In their discussion of the attachment process (chapter 4, p. 142), the authors mention an upward discharge from a television antenna that is not adequately reproduced on the cover of the book. [Note: a much better image of this discharge can be found in Uman (1991) or Newcott (1993).] Figure 7.24 shows the surface arcs produced by a rocket-triggered discharge, and Figure 7.25 shows how the production of such arcs depends on the peak current. This is very important material, of course, but it is probably more appropriate for chapter 18, on the effects of lightning, than it is for chapter 7. For some reason, the bibliography after chapter 13 has in lightning research is currently so fast that the book is already incomplete in several areas. Christian et al. (2003) have published seasonal distributions and other statistics for the global lightning dataset that is shown in Figure 2.12, including average zonal and meridional distributions throughout the year. The NMIMT lightning mapping array that is described in chapter 17 now has the capability of measuring the spatial and temporal development of lightning channels with an accuracy of a few tens of meters and a time-resolution of 10 μs (Behnke et al. 2003; Thomas et al. 2004). A recent book by Cooray (2003) gives more details on the phenomenology of high-voltage breakdown, the coupling of lightning-caused transients to power systems, and the methods of assessing the risk of lightning damage to structures. Finally, the recent observations of x-rays coming from natural and triggered discharges near the ground (Dwyer et al. 2003; Dwyer et al. 2004; Dwyer et al. 2005) are raising new questions about how very energetic (runaway) electrons are produced by the electrical breakdown of air at high pressures (Dwyer 2003), and the role that such radiation might play in the physics of lightning.

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