curvature tensor compensate each other. The theory of distant parallelism was unsuccessful despite the intense discussion in the letters exchanged between Einstein and Cartan. "The Einstein–Cartan correspondence shows—as Biezunski puts it—[that] these two men followed from the start parallel but distant paths."

The book ends with two contributions on cosmology. In the first Kerszberg reviews the dispute between Einstein and de Sitter during the years 1916–17 over the early applications of the theory of general relativity to the universe as a whole. Discussed here are the role of Mach's principle, the origin of inertia, the "distant masses" and the boundary conditions, as well as the universality of the integration constants appearing in the solutions of the field equations in general relativity. This section concludes with a summary by Ellis of the historical development in cosmology from the Einstein–de Sitter dispute to modern times (about 1960). This interesting contribution contains an extended bibliography that is of great value to any scholar of cosmology.

Let me conclude by saying that this first volume of the *Einstein Studies* devoted to the history of general relativity is a true and valuable source of information on the origin and development of Einstein's theory. The reader may only wonder why such a book had not been written decades ago.

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Nonequilibrium Hypersonic Aerothermodynamics

Chul Park

Wiley, New York, 1990. 358 pp. $59.50 hc ISBN 0-471-51093-9

Spacecraft entering planetary atmospheres create flow conditions that defy experimental laboratory simulation and require extension of theoretical models to include nonequilibrium processes. The logarithmic mass ratio in the rocket equations for spacecraft design places a great premium on thermally and aerodynamically efficient structures. This book covers the principal aspects of physics, chemistry and high-speed fluid dynamics that must be understood by those who would contribute to the aerodynamics and propulsion of future interplanetary space flight. Many of the methods are so new that no other book has this scope. Chul Park's initiative must be applauded.

The title helps specify the scope of the subject matter presented. Equilibrium thermodynamics was put on a firm physical base by quantum statistical mechanics, and the continuum theory of compressible fluid flows at hypersonic speeds—Mach numbers greater than five—was developed during the first space age, the 1960s. What we could not deal with adequately then were any but the simplest of rate processes: vibrational energy changes described by a relaxation time and chemical reactions described by the Arrhenius equation.

The fundamental problem is that interplanetary approach speeds, in the range of Mach number 30, lead to equilibria where chemical reactions, ionization and radiation all become important. But the bow shock wave enveloping the spacecraft first converts almost all of the incoming kinetic energy into Maxwellian translational energy within only a few molecular mean free paths. Thereafter all sorts of reactions occur with rates ranging over many orders of magnitude, including some that are slow compared to flow time for small probes but significant for large piloted spacecraft.

Park is well qualified to write this book. He has developed new experimental methods for laboratory research at NASA Ames Research Center; has written many sound research papers in theoretical and experimental aspects of the subject; and is actively involved with the emerging methods of computational fluid dynamics, computer-based techniques for solving the coupled sets of nonlinear partial differential equations. Much of the material in this book is drawn from a course he has taught at Stanford.

Who should study the book? Anyone who wants to work in space-vehicle aerodynamics or propulsion, implosion fusion or high-powered gas-dynamic lasers. Who can study the book successfully? The author says a familiarity with supersonic aerodynamics and with the book by Walter Vincenti and Charles Kruger, *Introduction to Physical Gas Dynamics* (Wiley, New York, 1965) are necessary. This reviewer agrees these are necessary but not sufficient conditions. Physicists can manage the necessarily brief review of basics and nomenclature but those with other backgrounds will have a tough time with the quantum mechanics of atoms and molecules; eigenfunctions; quantum numbers; the identification of atomic and molecular energy levels; and selection rules in line and band spectra. To ease this task the author includes in each chapter many helpful figures, several meaningful problems, lots of tables of data and a gratifyingly complete list of references in case the reader gets stuck. The student reader will be well advised to work all the problems in each chapter before proceeding to the next one.

The first five chapters deal with atoms and molecules, transitions between states, rate equations, fluid conservation equations and methods for setting up equations for computation. Included in Chapter 5 is a section charmingly titled "Pitfalls and Tricks," a refreshing reminder that art and skill are required in manipulating even the greatest computers.

Chapters 6 through 8 include a broad range of applications with both experimental and theoretical results being presented and discussed. This section of the book is actually a very authoritative assessment of our present level of knowledge and ignorance about the problems discussed in the opening paragraphs of this review. Chapter 9 concludes the work with reactions at surfaces, including evaporation and condensation. Heterogeneous reaction theory is far less advanced than gas phase theory so the text is necessarily more discursive and more empirical than the rest of the book. Inclusion of this topic is a wise choice in this reviewer's opinion simply because successful spacecraft design requires an integrated effort of aerodynamicists with materials experts: Hence some common language for communication is needed. Perhaps spacecraft materials books should end with a chapter on gas dynamics.

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NEW BOOKS

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