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Most matter in the Universe, from the deep interior of planets to the core of stars, is at high temperature or high pressure compared to the matter of our ordinary experience. This book offers a comprehensive introduction to the basic physical theory on matter at such extreme conditions and the mathematical modeling techniques involved in numerical simulations of its properties and behavior. Focusing on computational modeling, the book discusses topics such as the basic properties of dense plasmas; ionization physics; the physical mechanisms by which laser light is absorbed in matter; radiation transport in matter; the basics of hydrodynamics and shock-wave formation and propagation; and numerical simulation of radiation-hydrodynamics phenomenology. End-of-chapter exercises allow the reader to test their understanding of the material and introduce additional physics, making this an invaluable resource for researchers and graduate students in this broad and interdisciplinary area of physics.