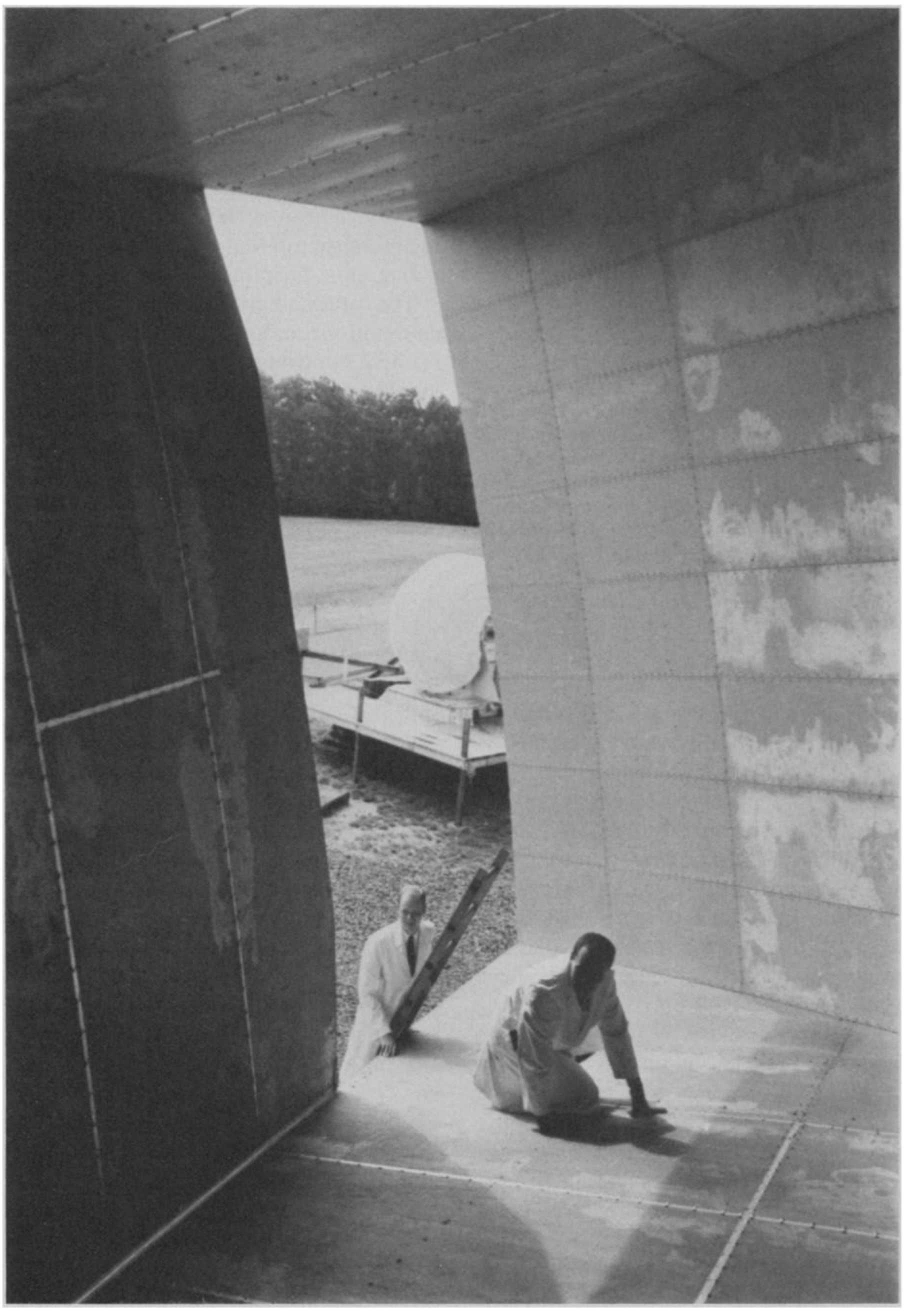
The Early Universe

The First Three Minutes. A Modern View of the Origins of the Universe. STEVEN WEINBERG. Basic Books, New York, 1977. x, 188 pp., illus., + plates. $8.95.

In 1965 a discovery was made that transformed our understanding of the universe and made possible the serious discussion of its early stages. This discussion has now been developed to the point where one speaks of "the standard model" of the early universe. It is this model which is the main subject of Steven Weinberg's new book, and especially the first three minutes, which give the book its title. It is written for the intelligent nonscientist (characterized by the author as a smart old attorney who expects to hear some convincing arguments before he makes up his mind).

The discovery that initiated this development was made by two radio astronomers, Arno A. Penzias and Robert W. Wilson, who found that at a wavelength of 7 centimeters the flux of cosmic radio noise arriving at the earth was a hundred times greater than expected. This excess was immediately identified by Robert H. Dicke, P. J. E. Peebles, P. G. Roll, and D. T. Wilkinson as belonging to a 3°K blackbody radiation field, the ashes of the primeval fireball. Subsequent measurements at various wavelengths have tended to confirm the thermal character of the radiation, although the clinching evidence will have to come from future measurements made above the earth's atmosphere.



Inside the Holmdel radio telescope. Robert W. Wilson watches as Arno A. Penzias tapes the joints of the 6-meter horn antenna. The taping was "part of an effort to eliminate any possible source of electrical noise from the antenna structure that might account for the 3°K microwave static observed in 1964–65. All such efforts only succeeded in reducing the observed microwave noise intensity very slightly, and the conclusion became inescapable that this microwave radiation is really of astronomical origin." [Bell Telephone Laboratories photograph; from *The First Three Minutes*]

One remarkable feature of this development is that it had been foreshadowed nearly 20 years earlier by George Gamow, who had suggested with Ralph Alpher and Robert Herman that nuclear interactions occurring close to the hot big-bang origin of the universe might be responsible for the formation of the elements heavier than hydrogen. Gamow pointed out that this would require a present temperature for the radiation of a few degrees absolute. His prediction was completely forgotten by 1965. Today it seems highly likely that it is correct and that most of the helium and perhaps most of the deuterium in the universe was made 100 seconds after the hot big bang.

All this makes a wonderful story, with precise physics operating in a fantastic context. This combination clearly fascinates Weinberg, and he communicates this fascination to the reader. With no mathematics and very clear physics he leads to the heart of the book, a series of six snapshots of the early universe, taken at intervals during each of which the temperature drops by a factor of 3. A few key formulas are developed in a mathematical supplement, but the book is intelligible without them.

Other features are a detailed account of how Penzias and Wilson made their great discovery (the "white dielectric material" with which pigeons coated the antenna throat was new to me) and an attempt to understand why Gamow's prediction was forgotten. I liked particularly Weinberg's statement that "our mistake is not that we take our theories too seriously, but that we do not take them seriously enough." This gives him the courage to discuss in the last chapter the first one-hundredth of a second, which occurred before his first snapshot. Here we read about some of the latest ideas in elementary particle physics; of gauge theories, asymptotic freedom, and phase transitions, which may well dominate the very early universe. Weinberg himself, of course, is a distinguished elementary particle physicist as well as a cosmologist. We shall need to draw on his ideas and those of his colleagues for understanding some earlier critical times such as the first 10^{-23} second and even the first 10^{-44} second, when quantum gravity comes into its own. I can imagine no better guide to such developments than Weinberg, and I am looking forward impatiently to his next popular book on cosmology.

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Solid State: A New Exposition

Solid State Physics. NEIL W. ASHCROFT and N. DAVID MERMIN. Holt, Rinehart and Winston, New York, 1976. xxii, 826 pp., illus. $19.95.

The past few years have seen a proliferation of textbooks of solid state physics. The near vacuum that existed before the publication of the first edition of Kittel's *Introduction to Solid State Physics* in 1953 has now become comfortably filled. Prior to 1953, to be sure, there were a few very important monographs and treatises, among them Sommerfeld and Bethe's article in the *Handbuch der Physik* (1933), Mott and Jones's *Theory and Properties of Metals and Alloys* (1936), and Seitz's *Modern Theory of Solids* (1940). These served to define the subject matter of the field, but they were not really textbooks. As Ziman has pointed out in a preface to his own excellent book *Principles of the Theory of Solids*, "A treatise expounds; a textbook explains." Kittel, Ziman, and now Ashcroft and Mermin have written important textbooks, each with its own pedagogical style, that delineate and explain the mainstream content of the field.

Some cynics have argued that the term "solid state physics" was coined in order to make it clear to government funding agencies, after World War II, that there were activities other than nuclear physics that deserved federal support. Traditional solid state physics, however codified, is largely concerned with experiments and theories pertaining to perfect (or nearly perfect) crystals and is directed toward microscopic description of physical phenomena on the basis of quantum and statistical mechanical ideas. Its range of subjects includes crystal structures, electron energy levels in solids, electronic conduction and other transport properties, surface effects, cohesive energy, lattice vibrations, magnetism, superconductivity, defects in crystals, and the special place of these phenomena in insulators, semiconductors, and metals. These are the subjects of primary concern in Ashcroft and Mermin's book. Superfluids, liquid crystals, polymers, and phase transitions, which belong to a larger field generally termed condensed matter physics, are not included, nor, for the most part, are metallurgically oriented matters having to do with atomistic and structural properties such as dislocations and alloy phase diagrams, which are now generally subsumed under the rubric of materials science.

Ashcroft and Mermin present the hues and nuances of solid state physics faithfully. Important approximations in theoretical expositions are characterized even when a full explanation would require a level of sophistication greater than the book presupposes. Detailed arguments that would interrupt the narrative flow are relegated to appendixes that are self-contained and that have been prepared as carefully as the text itself. This format (which has found its ultimate fulfillment in Nabokov's *Pale Fire*) is very useful here. The appendixes, together with well-constructed problems that probe the material discussed in each chapter somewhat more deeply, allow the book to be adapted for more advanced courses or more sophisticated applications.

The arrangement of the subject matter for a book such as this is far from fixed. For example, it is as logical to begin with a discussion of crystal structures and lattice vibrations as it is to begin with the free electron theory of metals. The former subject was the preferred beginning in the earlier textbooks, most likely because it did not require knowledge of quantum mechanics, which was not standard in a beginning solid state physics student's repertoire until fairly recently. It is more satisfactory historically and pedagogically for a book concerned primarily with the electronic properties of solids to begin with the Drude theory of metals as Ashcroft and Mermin do. Regrettably, the truly germinal 1926 paper by Pauli concerning paramagnetism is overlooked in their discussion of this theory, as it is in most others, and is relegated to the much later chapter on magnetism. At any rate, the authors neatly sidestep the problem connected with any linear arrangement of material by inserting a table listing the chapters that are prerequisite to any given part of the book, thereby leaving the instructor or reader with a special interest free to order the material to suit his or her needs. This feature should be particularly useful to those whose contact with the field and "need to know" are occasional.

Despite its diversity, the book is not fragmented, but flows smoothly from subject to subject. Its style is pleasant, its explanations are clear, and the choice of examples is tasteful. Its blemishes are minor and mostly of a technical character (in view of its importance, for example, k·p perturbation theory could have been presented more adequately). References to important papers and reviews could have been somewhat more copious and could certainly have been more accurate.

The basic concepts of solid state physics have found a wide variety of applications in chemistry, geology, and biology. An important new elementary textbook that provides a thorough, lucid, and well-balanced exposition and a means for self-education will surely enjoy a wide appeal. At the same time, however, Kittel's book, now in its fifth edition and on roughly the same introductory level (Ziman's being somewhat more advanced) should not be forgotten. It retains a starring role among beginning texts. Perhaps the top billing will now have to be shared.

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Chinese Artifacts

Metallurgical Remains of Ancient China. NOEL BARNARD and SATŌ TAMOTSU. Nichiōsha, Tokyo, 1975. xxx, 344 pp., illus. $99.50.

In his book *Bronze Casting and Bronze Alloys in Ancient China* (1961) Noel Barnard first presented his views on "the autochthonous nature of the discovery of metallurgy in China." Thinking that it would be useful "to explore the situation more fully" and in particular that "a comprehensive listing of sites yielding metal artifacts—prepared with typological and chronological arrangement of the data—should, when plotted in an appropriate manner onto base maps of China, demonstrate significant distribution patterns," Barnard enlisted the cooperation of Satō Tamotsu to compile the relevant data. The book under review presents the results of the research.

The book begins with a long and technical essay by Barnard, entitled "Origins of bronze casting in ancient China," that summarizes much essential information on such matters as alloy constitu-