tower endeavor into a large enterprise with strong interaction with society and its needs as seen in the career of one man who played a leading role that this book will have its most enduring impact. I heartily recommend it to the readers of PHYSICS TODAY.

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Solid State Diffusion

J. P. Stark
237 pp. Wiley, New York, 1976. $17.50

Diffusion in the solid state is fundamental to a host of important technological processes, from ancient metallurgy (the smelting of ores, the tempering of steel) to semiconductor-device fabrication. Since diffusion in solids takes place by the motion of lattice defects, especially vacancies, diffusion is also a means of studying the behavior of lattice vacancies. Because the behavior of vacancies is of great importance to atomic energy (in the areas of radiation damage, creep and sintering, for instance), the study of diffusion—especially in simple solids—grew enormously in the 1950's and 60's. At the present time, diffusion in some solids (such as close-packed metals, alkali and silver halides and elemental semiconductors) is for the most part understood, although some details are not clear and some controversy remains. The understanding of diffusion in body-centered-cubic metals and simple oxides is less advanced, and studies of more complex systems are only beginning. All this knowledge is summarized primarily in conference proceedings and review articles; fewer than ten texts or specialized monographs on diffusion in solids have appeared in the past fifteen years.

John P. Stark's *Solid State Diffusion* is a rather restricted theoretical monograph. Stark, who is Professor of Mechanical Engineering at the University of Texas, has published widely on both experimental and theoretical subjects in the field of diffusion in metals, and the book largely reflects his research interests. Most of the book is confined to volume diffusion by vacancy motion in dilute metallic alloys. The first two chapters are introductory, giving some solutions to the diffusion equation and a discussion of jump frequencies and phenomenological equations. The next four chapters are primarily devoted to matrix-algebraic treatment of vacancy diffusion in pure metals and in dilute alloys. Matrix methods of calculating correlation factors are given in great detail. In addition, the equations of the thermodynamics of irreversible processes are used and the cross terms are thoroughly discussed. The book closes with a short chapter on ultrafast diffusion, diffusion along short-circuiting paths and the near-surface effect.

Stark's book treats in detail several of his own research contributions, including the concentrations of vacancies in a temperature gradient and diffusion of impurities by divacancies. One of his conclusions on the latter, that the presence of rapidly moving, tightly bound divacancies does not increase the diffusion coefficient, appears at first glance to contradict both physical intuition and experimentally observed nonlinear Arrhenius plots.

The approach throughout is kinetic rather than atomistic. Thus, vacancy concentrations and vacancy–impurity binding are discussed in statistical terms, without much inquiry into the nature of the vacancy formation or binding energies. Stark develops his equations from both the random-walk and the phenomenological formalisms and achieves some sort of a synthesis.

The treatment is highly mathematical and not for the casual reader. The physics sometimes gets lost in the math. The book must be read from page one, and the reading is not made easier by occasionally imprecise language and an inadequate index. Experimental results are rarely mentioned. The book's strength is the detailed mathematical exposition; it is an ideal book for a graduate student or researcher who wants to learn the mathematical treatment of successive atomic jumps in medium-complicated systems.

Stark's book is close to John Manning's *Diffusion Kinetics for Atoms in Crystals* in content. Stark's treatment is more detailed; Manning ranges somewhat wider and deeper. The choice between the two is really a matter of taste. Neither is suitable as a text in an advanced-undergraduate or beginning-graduate materials-science course on diffusion (and how badly such a text is needed!). Both could be used in advanced graduate seminars.

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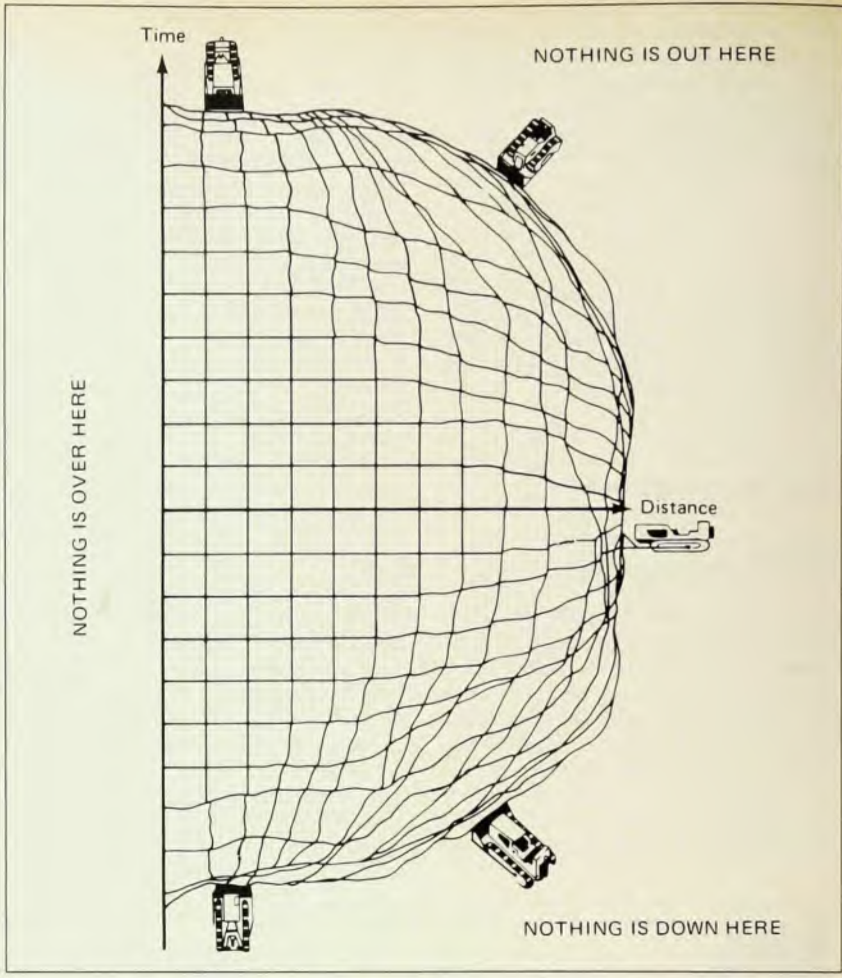
The Cosmic Frontiers of General Relativity

W. J. Kaufmann III
306 pp. Little, Brown, Boston, 1977.
$12.95 clothbound, $6.95 paperbound

Our culture no longer presumes that Man's immediate fate is tied to the stars, and so we spend incomparably less effort in studying them—as a fraction of our total effort—than did, for example, the neolithic people who built Stonehenge. William Kaufmann points out that the annual cost of even the Apollo project was less than one-third of what Americans spend on cigarettes and about equal to what they spend on dog food. Yet the day may not be far off when we shall use outer space again—to travel, to work, perhaps to survive. Kaufmann's new book is therefore timely: It vividly attempts to familiarize poets and liberal-arts students with some of the more arcane aspects of the modern cosmos.

The first two-fifths of the book contains an elementary introduction of the usual kind to special and general relativity and to the physics of stars. But the rest is quite unusual; it is devoted almost entirely to black holes. These come in Schwarzschild, Reissner–Nordstrøm, Kerr and Kerr–Newman varieties (having mass, mass and charge, mass and rotation, or mass and charge and rotation respectively). The book concentrates on Kerr holes, which are by far the most important in practice. A Kerr black hole is a spacetime warp with an incredibly complicated topology. It is connected smoothly to infinitely many universes similar to ours, rather like a branch point of an infinite-sheeted Riemann surface. Part of a Kerr hole could be realized when a rotating star collapses through its horizon under its own gravity, but the complete (theoretical) Kerr hole would have to be created from scratch, like a miniature universe—and perhaps even concurrently with the universe in which we live.



Squeezing in the infinite reaches of space-time. In Kaufmann's book bulldozers provide an analogy to the mathematical technique of conformal mapping that provides a "handle" on remote regions.

Kaufmann undertakes to discuss these complicated matters entirely without the help of mathematics. Not a single equation contaminates the text. For example, the invariant interval of special relativity is not defined here as $dx^2 + dy^2 + dz^2 - c^2dt^2$ but is, rather, described thus: "Three of the pieces that comprise the interval come from measurements of the distances (up–down, left–right, forward–back) . . . the fourth piece comes from the amount of time . . ." Again, in the description of the Penrose diagrams so useful for the understanding of black holes, we are told to think of bulldozers (and a figure illustrates this) bringing the infinite portions of spacetime to finite positions where they can be looked at and studied. The simple transformation $x = \tan x'$, which pulls distances in from infinity and which would clarify the matter at once to anyone having even the rudiments of a mathematical education, is barred by the self-imposed rules of the game. And, of course, there are no references to the literature.

Kaufmann's method is largely graphical. Over 200 well-conceived and finely executed diagrams guide the reader's intuition. The two main devices are Penrose diagrams and a long series of illustrations (rather too long, for my taste) showing what astronauts (always carefully designated as "he or she") would see on approaching—or passing through—a black hole along various paths. As for the Penrose diagrams, we are told how to fit the various blocks together and what they mean physically. Of course, no justification for all this can be made without recourse to the mathematics of the Kerr solution, and so everything must be taken on trust. Nevertheless, by playing with these diagrams the reader should come to