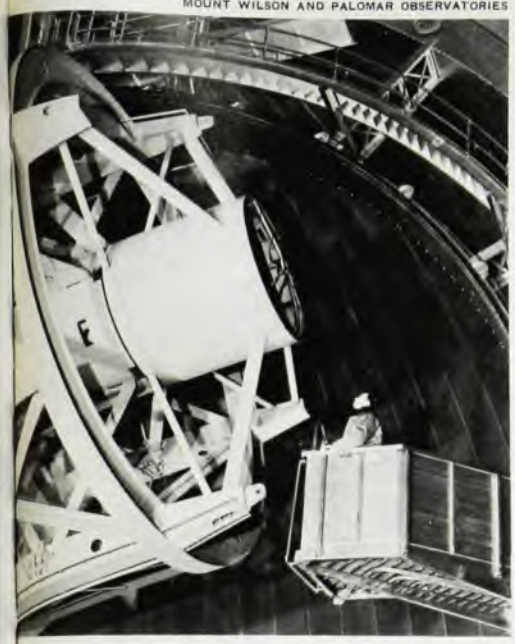
MOUNT WILSON AND PALOMAR OBSERVATORIES



Experimental astronomer at Palomar Observatories riding an elevator to the prime focus observing position.

to view astronomy under a truly new light, with the field of experimentation very much extended . . ." On the other hand, space research seems rather aloof from astronomy when he says "The 'intersection' of the two sets 'astronomy' and 'space research' is in fact still rather small in extent . . ." The author says he has tried to underline these aspects of space research that he considers important, but he concludes that "one cannot yet say that astronomy has learned very much from the utilization of rockets, satellites, and extra-terrestrial probes." I suggest that a re-evaluation of the former would lead to an opposite conclusion on the latter.

After 50 pages devoted to orbits and astronautics, there are ten on the moon and two pages on Mars and Venus. The discussion then shifts to a critique of possible life in other inhabited worlds for 24 pages, and ends with a defense of ground-based observations against the glamor and financial competition of space technology. One can understand this selection and emphasis in terms of the subtheme mentioned above. From the information presented in this book one would indeed conclude that space research had added very little to our knowledge of astronomy. Fortunately, there are much broader perspectives in numerous other books.

That space observations will continue to be a vital part of astronomy can hardly be doubted. No rational group of scientists would pass up a chance to extend their range of spectral coverage by a factor of 10^4 or to observe the messenger particles streaming through space. The relative roles of solar-system probes, observational satellites, rockets, balloons, and ground-based observatories have been considered by panels of competent scientists. Their recommendations have been taken seriously by US Government funding agencies. It appears likely to me that a reasonably balanced astronomy program will evolve at a level that reflects the relative persuasive pressures of astronomers in competition with other groups who seek the Government dollar.

Young scientists are the intended audience. The level of presentation is at the sophomore undergraduate level. In spite of the loose connection between chapters there is good continuity within each chapter. Very few flaws appear in the translation and only a few minor misprints are noted. Because of its brevity this book should attract the browsing student and may stimulate him to read further until he recognizes the scope of space research.

The author is well qualified to discuss the importance of ground-based observations (or experiments) to astronomy. He had been associated with the French observatories at Nice and Meudon for some years, where he has made numerous contributions, particularly to the theory of stellar atmospheres.

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Boston Studies in The Philosophy of Science, Vols. IV, V

R. S. Cohen, Marx W. Wartofsky, *eds.*
(Conf. proc., Boston Colloquium for the Philosophy of Science 1966/1968.) 537 pp. Humanities Press, Inc., New York, 1969. Volume IV, $20.00; volume V, $16.75

Boston Studies in the Philosophy of Science, Vol. VI: Ernst Mach, Physicist and Philosopher.

Robert Cohen, Raymond Seeger, *eds.*
(Annual Meeting of the American Association for the Advancement Of Science, Washington, D. C., 27 December 1966.) 295 pp. Humanities Press, New York, 1970. $11.50

Most of the essays in volumes IV and V of this series on Ernst Mach were originally presented as lectures at the Boston Colloquium for the Philosophy of Science during the years 1966–68; about half of the essays in volume VI were contributions to an AAAS symposium in Washington, D.C., in December 1966, commemorating the 50th anniversary of Mach's death. While the first two of these three volumes contain many individual essays of considerable interest (volume IV being devoted primarily to the social and behavioral sciences, volume V primarily to the natural sciences), only the Mach volume possesses sufficient coherence to be briefly discussed as a whole. I shall therefore focus my attention on the Mach volume, with occasional allusions to essays in the other volumes.

All in all, the Mach volume is very satisfying: besides covering most aspects of Mach's thought, it contains a short account of his life and a full bibliography (including all English translations); the illustrations are excellent and include, as frontispiece, the reproduction of an excellent portrait of Mach (painter, date, and present location unfortunately are not disclosed). Now, for some details.

The phrases "Mach bands" (in the psychology of visual perception), "Mach-Breuer-Brown theory" (concerning the role in motion perception of the semicircular canals of the inner ear), "Mach's principle" (in relativity theory), "Mach angle," "Mach wave," "Mach reflection," and "Mach number" (in supersonic aerodynamics), attest not only to the breadth of Mach's interests in natural phenomena but also to his impressive ability to hit on the deepest issues in almost every subject he investigated—issues that in many cases remain fully alive today. This becomes apparent from the expositions of Mach's scientific work by Floyd Ratliff (psychophysics), by Wolfgang Merzkirch and by Raymond Seeger (gas dynamics), and by Hubert Goenner (critique of classical mechanics).

Mach discovered the bands bearing his name accidentally when he undertook some studies in optical perception immediately following the completion of his doctoral studies in Vienna in 1860. These bands constitute an extraordinarily compelling example of an optical illusion and—somewhat surprisingly, since they are normally overlooked—are very common even under natural conditions. Indeed, whenever an object casts a shadow in sunlight the phenomenon in question can be detected in the form of a dark band at the boundary between full-shadow (umbra) and half-shadow (penumbra), and a bright band at the boundary between half-shadow and full sunlight. Mach understood the illusory character of the bands (which, incidentally, can even be photographed, in the sense that the resulting picture exhibits the same illusion as the original distribution of light and shadow). He also deduced that the origin of the illusion lies in certain properties of the photosensitive elements in the retina, in particular the inhibitory influence of a stimulated element on neighboring elements. This insight of Mach's was ignored until remarked upon by Georg von Békésy in his 1928 work on hearing. The continuing importance of Mach bands is implied in the title of Ratliff's recent book, *Mach Bands: Quantitative Studies on Neural Networks in the Retina* (1965), which includes an En-

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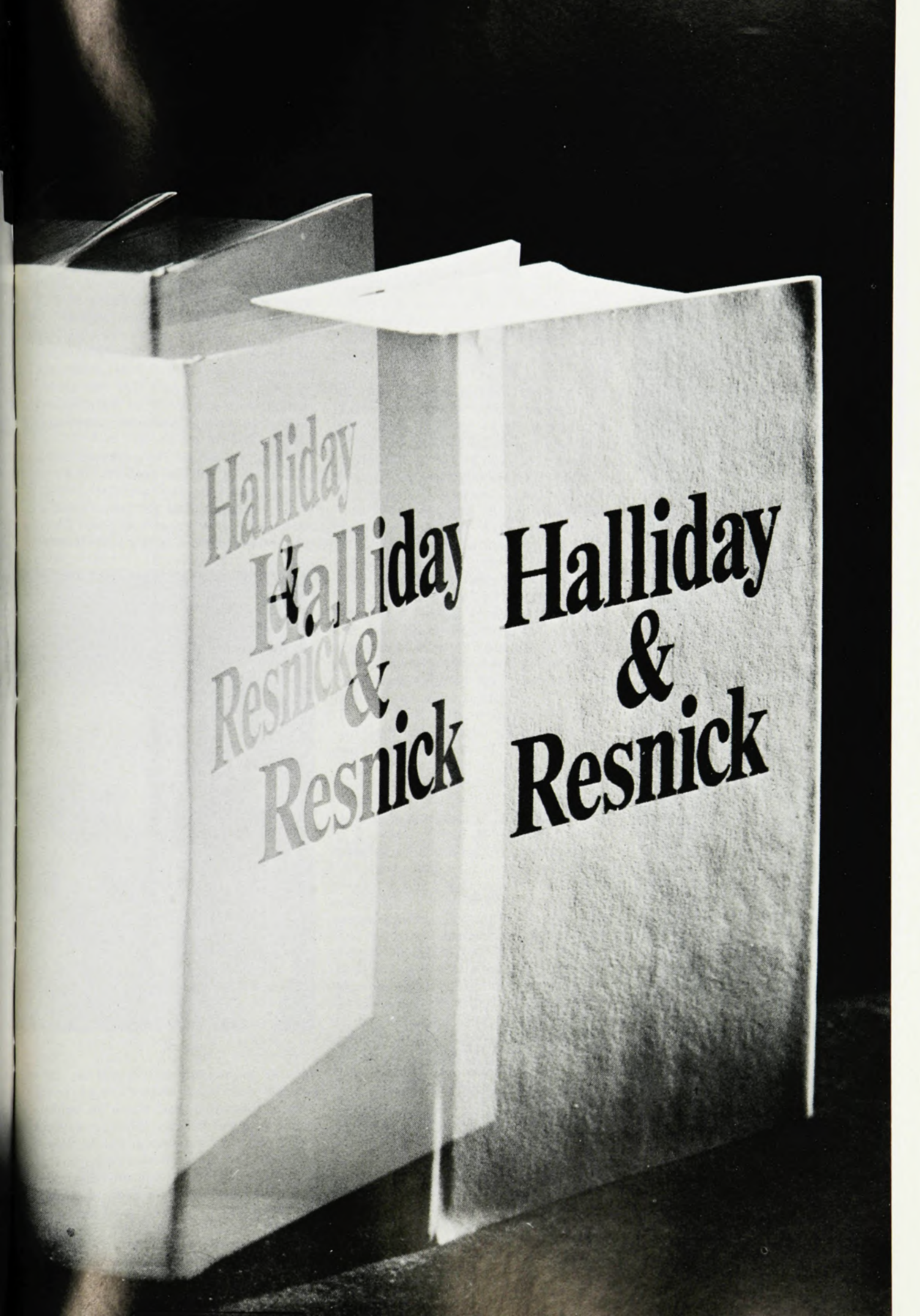
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glish translation of Mach's six papers on the subject.

With respect to Mach's experimental studies on shock waves, it is notable both that the so-called Mach–Zehnder interferometer (developed by Mach and his son Ludwig in the 1890's) continues to be used for the study of shockwave interaction, and that no adequate theory for this interaction is yet available (as Seeger points out, page 66).

With respect to Mach's principle, it is first important to distinguish Mach's own formulation—which Mach himself never elevated to the status of a "principle"—from the many different versions under active consideration today. This task is well accomplished by Goenner's compact but lucid essay (which will, however, be easy reading only for those already acquainted with the recent literature on general relativity). What Mach did was to point out, in his critique of Newton's concept of absolute rotation, that the alleged properties of absolute (as opposed to relative) motion—namely, the appearance of centrifugal (or more generally, inertial) forces—might well be attributable to an interaction between a given (rotating) body and the remaining matter in the universe (in particular, the fixed stars). Whether this idea of Mach's is, strictly speaking, incorporated in general relativity (as Einstein hoped) is difficult to determine owing to the current lack of exact solutions of Einstein's field equations for rotating bodies; recent approximate solutions (D. Brill and J. Coehn) seem to support Mach's idea. On the other hand, Einstein's idea (which he somewhat anachronously refers back to Mach) that the character of space-time (the $g_{\mu\nu}$-field) be fully determined by the distribution of matter in the universe (the matter tensor, $T^{\mu\nu}$) is definitely not satisfied by general relativity (unless one arbitrarily imposes the condition that space is finite). All this and much more is carefully explained by Goenner with literally scores of references to the recent literature.

Even those who recognize Mach's superb endowments as a scientist tend to be rather scandalized at his attitude toward atomism, an attitude that seems to have been at best sceptical and at worst openly hostile. Often Mach's "erroneous" views concerning atoms are ascribed to the excessive narrowness or rigidity of his philosophical views. It is, therefore, of some interest that at the very outset of his academic career and prior to any detailed formulation of his philosophy of science, Mach found atomism acceptable as a (probably only temporary) expedient, which "brings the phenomena into a simple and visual relationship" (Erwin Hiebert, "Mach's Early Views on Atomism," page 87). Indeed he goes so far as to distinguish aether-atoms and matter-atoms in a way that was perfectly conventional in the 1860's. Subsequently, while many physical scientists were becoming more and more convinced of the reality of atoms, Mach became more and more sceptical, so that eventually he rejected their existence altogether. This evolution in Mach's ideas appears in part explicable, according to Hiebert, as a result of his growing interest in psychophysical investigations and his growing conviction that the atomic theory was not only useless but might even be a hindrance in psychophysics. But, as Milic Capek points out ("Ernst Mach's Biological Theory of Knowledge," volume V, page 401), it was precisely in psychophysics that Mach himself relied somewhat uncritically on an analogue of physical atoms, namely, his "elements" (which were supposed to include sensations as well as volitions, memories, and so on).

Whatever its shortcomings, Mach's concept of an element seems to be a precursor of the more sophisticated concept of a "discriminated existent," which, the neurophysiologist Robert Efron persuasively argues, ought to be fundamental in the study of perception. Efron not only holds that "The phenomena of consciousness must be understood before one can hope to explain them in terms of neural action" ("What is Perception?", volume IV, page 171) but shows in detail how his methodological principles can be applied to clarify the nature of "visual object agnosia," a very puzzling mental disorder in which the subject's visual perception seems normal but he is unable to name seen objects (though he *can* identify and

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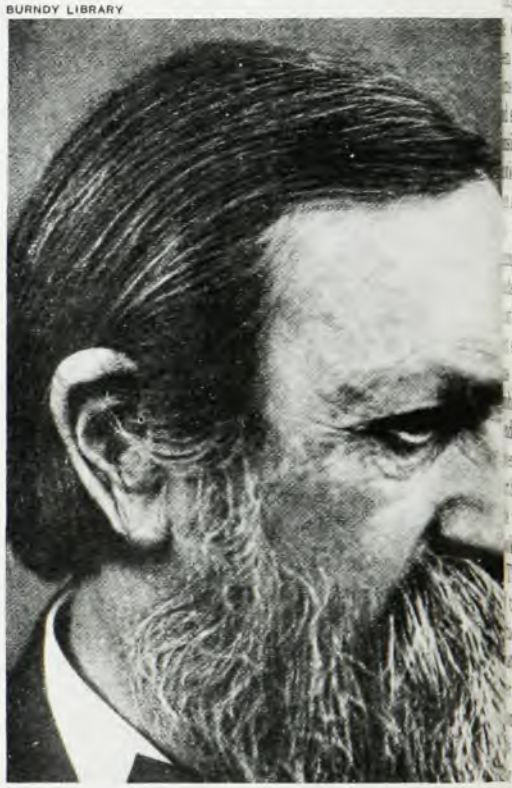

MACH

name the same objects by touch). It appears to me that Efron's insistence on the priority of perceived over neural units would have been quite congenial to Mach's way of thinking.

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Large Elastic Deformations

By A. E. Green, and J. E. Adkins
2nd ed. 324 pp. Oxford U.P., New York (London), 1971. $15.25

In the last quarter century the subject of finite elasticity has undergone a rapid development, until it is now an established branch of theoretical mechanics. The authors of this book, Albert E. Green and the late John E. Adkins, are two of the earliest and most distinguished workers in the field. The book is a revised version of an earlier work published in 1960, from which it differs mainly in the omission of the chapters on viscoelastic materials and stability. Both of these subjects have undergone so rapid a development in the last ten years that to cover them adequately would have required a very considerable enlargement of the work. In addition, the chapter on thermoelasticity has been changed. In it the governing equations and the equation relating stress and strain-energy are now derived, with considerations of invariance under rigid motion, from an energy-balance equation and an entropy production inequality. At various other points in the book changes of a minor character have been made that reflect the increased sophistication of our point of view on the subject since the earlier version of the book was written. Although the range of problems discussed has not been extended significantly, references are given to the more recent papers in which further problems have been solved with the various techniques discussed in the book.

The book presents the basic theory of the mechanics of elastic materials, which can be subjected to large deformations. It derives in an elegant manner the form of the strain-energy function for isotropic materials, for materials that have transverse isotropy, and for symmetries appropriate to each of the crystal classes. The authors discuss the effects of kinematic constraints, such as those arising from incompressibility of the material, or the incorporation in it of inextensible cords. Solutions to problems involving a high degree of symmetry, such as simple extension, biaxial extension, torsion and flexure are discussed in the case when the material is incompressible and isotropic and, in some instances, when it has transverse isotropy. Successive approximations in the solution of problems involving less symmetry, applicable to elastic materials subjected to small finite deformations, is also treated.

Other chapters include the theory of elastic membranes, the experimental determination of the strain-energy function for vulcanized rubber and the experimental verification of some of the predictions of finite elasticity theory and many other topics. As a whole, the book illustrates well the power of the phenomenological theory of large elastic deformations to solve problems and make valid predictions in the branch of physics with which it is concerned.

In both the present edition and the earlier edition, the authors have tried to minimize overlap with the material contained in *Theoretical Elasticity* by Green and W. Zerna. This has led to the omission of certain topics for which one immediately looks in a book on large elastic deformations, such as the theory of the superposition of small deformations on large deformations and the results of Green and Richard Shield on the superposition of small torsions on finite extension of a rod—surely one of the most elegant results in the mechanics of continua.

The book is written in a very forthright manner and has great clarity. It does, however, assume a considerable measure of sophistication on the part of the reader and, while not a book for beginners, it is surely a classic in the field and should be part of the library of any workers interested in finite deformations.

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new books

CONFERENCE PROCEEDINGS

Advances in Cryogenic Engineering, Vol. 16 (Conf. proc. 1970 Cryogenic Engineering Conference, 17–19 June, Univ. of Colo.). K. D. Timmerhaus, ed. 509 pp. Plenum, New York, 1971. $30.00

The Crab Nebula (Conf. proc. International Astronomical Union Symposium No. 46, 5–7 Aug. 1970, Jodrell Bank, UK). R. D. Davies, F. G. Smith, eds. 470 pp. Springer-Verlag, New York, 1971. $30.50

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Geological Problems in Lunar and Planetary Research, Vol. 25. J. Green, ed. 736 pp. American Astronautical Society, Tarzana, Calif., 1971

Hyperfine Interactions in Excited Nuclei, Vol. 1. G. Goldring, R. Kalish, eds. 360 pp. Gordon and Breach, New York, 1971. $27.50

Light Scattering in Solids (Conf. proc.