the sole example of dispersive waves and, at most, only a few remarks indicate the sources of waves.

The authors of this book, who are experimental physicists, never present mathematics for its own sake; however, the book lacks the richness of physical examples, data, and hands-on experimentation of, say, Frank Crawford's *Waves*. The computer program supplied as an appendix is designed to display wave phenomena on a microcomputer screen. It will undoubtedly please many readers of the book, but its treatment is not for the novice.

Teachers using this book should be prepared to provide background on partial derivatives and the differential form of Maxwell's equations, as the authors refer the reader to other books for development of these topics. On the other hand, the problems (nearly all answered in the back of the book) are plentiful and appropriate, the writing is clear, and the development proceeds at a reasonable pace. Anyone teaching a course on wave phenomena would do well to consider *Vibrations and Waves* as a possible text.

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The Physics and Chemistry of Color: The Fifteen Causes of Color

Kurt Nassau
454 pp. Wiley–Interscience, New York 1983. $43.95

"There appears to be no book covering the wide voids between the extreme of the monograph and general expositions on color, books on optics that deal with light but only peripherally with color, and books on color measurement and color perception. This book is intended to fill this serious gap." Kurt Nassau, a research scientist at AT&T Bell Laboratories, has done an admirable job filling this "serious gap." The book is well-illustrated, with clear, accurate and generally complete discussions at the advanced undergraduate level of the great wealth of causes of color, with many examples from science, art, and everyday life. Supplementary specialized mathematical or advanced topics, such as basic atomic physics (term symbols, selection rules, and the like), band theory and incandescence equations are relegated to appendices.

It is known that virtually all color effects are due (at some level) to the motions of electrons, and Nassau proves a knowledgeable guide in the domains where a variety of electron effects are present: crystals, semiconductors, and complex molecules—his fields of research. Consider variations within just one of the "15 causes": ligand fields, the electric fields at an atom of a transition metal that are due to the electron orbitals of neighboring atoms in a crystal. Suppose aluminum oxide (colorless sapphire) is doped with 1% Cr_2O_3; each of the five 3d orbitals of the resulting Cr^{3+} ions is shifted, but not all by the same amount. Light of the proper color will cause transitions involving these split levels, and will therefore be absorbed. Two such resonance absorptions are in the violet and the green–yellow (broadened by vibrational interactions), leaving deep red and a little blue to pass through. As a result, we have the blood red of the ruby.

The spatial symmetry of the ligands causes resonances to differ along different axes. Therefore the color of the transmitted light will depend upon its plane of polarization, varying between purple-red and orange-red—an effect known as pleochroism. Increase the Cr_2O_3 doping to 10% and the ligand fields are weakened, giving a colorless crystal. Heat this crystal, reducing the fields still further, and a green color results, an effect known as thermochroism. Increasing the Cr_2O_3 concentration to 60% also produces a green color; but now subject the crystal to enormous pressures of, say, 100 kilobar, and the ruby red color returns—an effect called piezochroism.

I have minor disagreements with Nassau's placement of some topics. For example, the spectacular blue interference colors of the *Morpho* butterfly are described in the chapter "Colorants of Many Types," rather than in "Interference and Diffraction." Holography is treated in a hodge-podge chapter that includes the physiology and biochemistry of human vision; it, too, seems better suited to the chapter on "Interference and Diffraction." However, I cannot fault Nassau for omissions; this is the most complete book I know of at any level on the causes of color. There are extensive discussions of color produced by molecular vibrations and rotations, band gaps and charge transfer effects, interference, diffraction, dispersion and scattering—even 19 varieties of luminescence—to name but a few of the topics.

The Physics and Chemistry of Color is to be strongly recommended, both as a reference and as an ideal text for "special topics" classes on color.

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book note

Newton at the Bat: The Science in Sports
Edited by Eric W. Schrier and William F. Allman
178 pp. Scribners, New York, 1984, $14.95

Why does a boomerang come back? This question and many others pertaining to the physics of sports are answered in this collection of essays that have been contributed to *Science 84* by a number of authors. The book is divided into four parts: "Balls and Other Flying Objects" discusses the physics of the motion of baseballs, golf balls, frisbees and the like; the second part, "Gear," deals with tennis racquets, bikes, skis, sails and gliders as viewed from the scientist's eye; the third part, "The Body," addresses the physiological aspects of sports, such as weight control, perspiration and the biophysical aspects of the exercising body; and the last part, "Form," is an amalgam of essays on subjects ranging from the ballistics of skiing to the construction of darts.

To those active in sports, *Newton at the Bat* will supply a theoretical backing that will make sports much more