

BOOK REVIEWS

Reliable Spectroradiometry, by Henry J. Kostkowski, Spectroradiometry Consulting, P.O. Box 2747, La Plata, Maryland, 20646-2747, 1997. xii + 609 pp. \$150 List (Special until June 1, 1998—\$120)

This book is a treasure-house of information for the practicing spectroradiometrist. Although specifically written to provide a comprehensive description of the concepts, devices, and procedures required for the reliable measurement of spectral irradiance and spectral radiance (from 100–2500 nm), this book presents material that is crucial to obtaining accurate measurements of any spectroradiometric quantity, and, subsequently, any quantity or effect calculated from spectroradiometric measurements.

The author has divided the 22 chapters of the book into three parts, each part addressing one of the major causes of significant errors in spectroradiometry: the characteristics of the radiant flux itself, the characteristics of the instruments and standards used to measure this flux, and the specific scheme or procedure used in the measurement process. Because the book is intended to be used as a handbook while planning and making measurements, the material presented is extensive and most of the chapters in Parts I and II can stand alone as reference material. The topics in these chapters are arranged pedagogically to cover all aspects of spectroradiometric measurements. However, realizing that assimilating information in this manner can be an intimidating process to any experimentalist, the author has written Part III to enable the reader to get into actual measurements as soon as possible, immediately after the introduction in Chapter 1, if desired. Part III works through the entire measurement plan, addressing all the topics of Parts I and II in an abbreviated manner, and in the order and context in which they are required when performing a measurement.

Chapter 1 is the introduction, defining and illustrating the usual terms such as spectroradiometry, spectroradiometric quantities, measurement accuracy, spectral irradiance, spectral distributions, a basic spectroradiometer, ending with the flux responsivity of a spectroradiometer, the measurement equation, and the well-known basic equation relating four quantities: the radiant quantity we wish to measure, the known same quantity for the calibration standard, and the two signals from the monochromator, one for each of these two light sources. I suspect that this simple equation is all that is used by many of us for our measurements. The remainder of the book is written to show us when this equation is no longer valid, and how to correct it.

Part I considers how various characteristics of the incident radiation may affect the output signal of the spectroradiometer. The titles of the 6 chapters (148 pages) in this part are like a check-list of concerns: nonlinearity, directional and positional effects, spectral scattering, spectral distortion, polarization effects, and size-of-source effect. Each of these effects is discussed, the measurement equation is altered to show how it is affected, and techniques are introduced to show how to measure the effect and determine the uncertainty involved, both for spectral irradiance and spectral radiance. Useful tips are scattered throughout the discussion, advantages and disadvantages of different setups are pointed out, and sources of materials are mentioned. Chapter 2 (Nonlinearity) discusses the use of the inverse square law, beam attenuation, and beam addition to determine the nonlinearity coefficients of the system. Chapter 3 explains the use of averaging spheres and reflecting and transmitting diffusers to mitigate the problems involved when the system responsivity depends on the direction of the incident flux and on its position in the entrance aperture. I found Chapters 4 (Spectral Scattering) and 5 (Spectral Distortion) particularly interesting, although they will require careful study for thorough understanding. In Chapter 4, the author starts by showing the seriousness of the scattering problem within a monochromator and then incorporates this effect into the measurement equation, which gives us a means of quantitatively dealing with it. He describes how to evaluate the magnitude of the problem, how to reduce it, and how to correct for it. All this leads to a discussion of the slit-scattering function, and deconvolution. Chapter 5 tackles the issue of measuring a source whose spectral output contains structure or curvature within the bandpass of your monochromator. Various situations are discussed, including spectral lines within a continuum, different wavelength step sizes, effect of the shape of the slit-scattering function, and the means of obtaining an average value. Chapter 6 (Polarization Effects) serves as a good introduction to the topic, including practical examples describing how to obtain the required components of the polarization properties, although I must admit I have usually done what the author advises: postpone dealing with the math until confronted with polarization problems in my measurements. Chapter 7 shows how to evaluate the size-of-source effect, caused by scattering in the fore-optics to the spectroradiometer, which causes an effect only when the source area is imaged into the system.

Part II consists of 9 chapters (237 pages), which deal with the equipment used in spectroradiometry—standards, instruments (optics, monochromators, control devices), and detectors. Chapters 8 and 9 consider the spectral irradiance and spectral radiance standards available,

mainly from NIST, and provide detailed information on their characteristics and application. The use of detector standards (e.g., cryogenic radiometers, light-trapped photodiodes) is also discussed. Chapter 10 (Wavelength Standards) is a welcome inclusion. The careful selection of the appropriate wavelength emission lines and their use to perform the wavelength calibration of the monochromator are discussed, together with the lamps used to provide these lines—pencil discharge lamps, hollow cathode discharge lamps, and electrodeless discharge lamps. Chapter 11 (Fore-optics and the Monochromator) starts with a discussion of the diffusers and imaging optics required for the insertion of the light from the source into the monochromator. This is followed with a discussion of 10 important characteristics of a monochromator to be considered when selecting this component of the measurement system. Chapters 12–15 are spent discussing the spectroradiometer detector, which must measure the tiny amount of radiant flux emerging from the exit slit of the monochromator. A chapter is devoted to each of: the photomultiplier, the silicon photodiode, the germanium photodiode and lead sulfide detector, and 5 types of multi-channel detectors. For each of these detectors, the basic operation of the detector is briefly described, and wavelength range, signal-to-noise ratio, stability, linearity, uniformity, and response time are discussed within the framework of typical spectroradiometric applications. Chapter 16 describes basic readout, automation, and positioning devices.

Part III (6 chapters, 170 pages) applies the information presented in the first two parts to an actual measurement process. To emphasize the importance of an uncertainty analysis from the very beginning of the experimental design, Chapter 17 is devoted to discussing uncertainties, including the latest approach embodied in the *ISO Guide to the Expression of Uncertainty in Measurement*. In the remaining chapters (18 to 22) the author leads us step-by-step through a 10-step measurement plan: defining the measurement problem (with potential errors), selecting the required standards and equipment, characterizing the spectroradiometer and the measurement configuration, determining the optimum schedule for acquiring the data, performing the actual measurements, analyzing the data, and preparing an uncertainty report. The many checklists, design and measurement tips and suggestions, together with a worked example, make this book an invaluable reference. The worked example, measurement of the solar spectral irradiance at the earth's surface between 295–315 nm, is of interest not only for its own sake, but because the difficulty of this measurement requires the evaluation of most of the errors possible in a spectral (irradiance) measurement.

All equation development is centered around the measurement equation, which relates measured quantities and quantities obtained from measurement standards. The derivation of several other useful equations related to the basic behavior of devices such as spheres and gratings is relegated to one of the 7 appendixes. The other six

appendixes cover: units, a list of commercial suppliers of equipment referred to in the text, an introduction to matrix operations, several computer programs, an extensive list of useful spectral calibration wavelengths, and a list of commercial suppliers of spectral standard lamps and/or calibrations.

The 5-page index seemed sparse—two items that I encountered while reading the book and for which I wanted the original description were not listed in the index.

The book is not a textbook, although it teaches and explains. It does not have the elaborate formatting of modern textbooks with wide margins containing associated information, attention-catching fonts, nor color photos and drawings. In fact, there is no color other than black and white throughout the book. However, the author has used the 8.5" × 11" format of the book to present tables and figures that are large, clear, and well labeled. (You can add your own color by highlighting the items that are important to *you*.) He has also chosen to present all the tables and figures at the end of each chapter. While this requires additional page flipping while reading the chapter, it simplifies searching for these items when reading other chapters.

The author claims that he has assumed the reader has no prior knowledge of spectroradiometry, nor extensive background in mathematics; just an introductory college level ability in physics and math. In general this is true, but it must not be assumed that the book is easy to read and understand. The author has done an admirable job of presenting the material in a graded manner. Most of us will find that the book contains material that we can easily comprehend, but that we are gradually led into complexities that will tax our abilities. The comforting realization is that we are not led into the unknown and abandoned, "as an exercise for the reader." For each of the complexities, the author has set up the procedures for measuring the size of the effect, evaluating the associated uncertainty, and then providing us with a worked example from his experience.

The author has drawn extensively from his experience working at NIST. As a result, most of the references are to work done at NIST, and the information and worked examples using measurement standards relate mainly to standards available from NIST. While this may be a slight deterrent to the international reader who obtains his standards from other national laboratories, the overall intent of the book to present good measurement methodology and techniques in a field of measurement, where 1% uncertainty is difficult to obtain, is not seriously diminished.

The author has appropriately chosen the name for his book—RELIABLE spectroradiometry. Other words such as *practical* spectroradiometry come to mind, but the concept of *reliable* takes practical one step further, adding accuracy and the evaluation of uncertainty. This book does that admirably.

I have no hesitation in recommending this book as one of the basics for the reference library of anyone who must

develop or evaluate any system requiring spectral optical radiation measurements. To those who are just entering the field, assimilating the extensive amount of material will present a formidable but surmountable challenge; to those who are already in the field, this book presents an inspiration.

ARNOLD A. GAERTNER

The Reproduction of Colour, 5th Edition, by Dr. R. W. G. Hunt, Fountain Press, Kensington-upon-Thames, England, 1995, 814 pp. \$90

“The fundamental principles of colour reproduction, whether by photography, television, or printing, are presented in the hopes that all those engaged in producing, selling, buying or using colour pictures will be able to see the nature of the problems they encounter.” Dr. R. W. G. Hunt, pp. 21–22

Robert Hunt’s book, *The Reproduction of Colour*, was first published in 1957. The fifth edition is now available. When a book is continued for five editions, you may be assured of two facts. The first is that readers have found that it meets a critical need, and second that all the potential kinks have long since been ironed out. Over the years *The Reproduction of Colour* has come to be recognized as one of the standard reference books essential for any color library.

While much progress has been made during the forty years since the first edition, the basic principles still hold. Each edition has kept pace with the new research and trends in reproduction. The *Fifth Edition* contains not only those original basic principles, but also the up-to-date information on the new technologies and their industrial applications.

For those who have never heard of this book before, here is the one paragraph summary of its aim and contents. The purpose of the book is to set forth the fundamental principles of color reproduction. The book is divided into five parts. Part I on Fundamentals introduces all the basic general principles. It includes 11 chapters on spectral and trichromatic reproduction, additive and subtractive mixing, visual appreciation, tone reproduction, the color triangle, color standards and calculations, colorimetry and light sources, and ending with objectives in color reproduction. Parts II through IV are on specific technologies. Part II on Colour Photography includes chapters on subtractive methods, reflection prints, quantitative color photography, masking and colored couplers, printing color negatives, chemistry, and image structure. Part III Colour Television covers transmission of color television signals, electronic cameras, display devices, N.T.S.C. and other systems, the use of color film, video cassettes, and pictures from computers. Part IV on Colour

Printing deals with photomechanical principles, preparing copy, practical making in making separations, color scanners, and digital pictures. Part V is Evaluating Colour Appearance. These are followed by appendices on matrix algebra, useful colorimetric tables, photometric units, and photographic parameters. The book ends with an extensive index.

As is always the case, the dilemma for owners of earlier editions is the question, is this new edition worth my additional investment? Here, I must be truthful, one item has been shortened; one item has stayed the same; and much has been added. The title has been shortened from *The Reproduction of Colour in Photography, Printing, and Television* to *The Reproduction of Colour*. The price of the *Fourth Edition* was \$89.95, and as you can see above, the current edition is essentially the same. Comparing to the *Fourth Edition*—what has been added? 814 pages up from 640; 32 chapters up from 29, 5 parts up from the original 4; and much more color.

I shall emphasize what is new in the *Fifth Edition*. Readers who want to know more about the earlier editions are invited to read the reviews of the *Third Edition* by Wright [1, 114–116 (1976)] and Maitland [2, 146–148 (1977)], and the *Fourth Edition* by MacAdam [13, 399 (1988)].

First I must say, the *Fifth Edition* is more colorful. Many of the figures have color added to them, which make their meaning easier to assimilate. They are found throughout the book from diagrammatic representations of cross-sections of photographic film, to colored ray tracings in a beam splitting projector with liquid crystal arrays, to hue angle vs. hue quadrature in color-appearance modeling. Also, more full color plates have been added. Although I didn’t count the number, I feel confident that there are many more than the 39 in the previous edition.

The whole text has been examined for relevance to the present day technologies. Sprinkled throughout the first four sections of the book at the appropriate points are new descriptions of direct broadcasting by satellite, high-definition television, CCD sensors, electronic news gathering, camcorders, electronic still cameras, liquid crystal displays, photo CDs, and prepress proofing. I found the explanation of liquid crystal displays particularly clear.

As a reflection of the newest trends and “hot” concerns of research, digital reproduction and color-appearance modeling have now been included in this text. While references and material have been updated throughout the book, the bulk of the new material is found in the three new chapters. They are Chapter 30 entitled Digital Pictures and Desktop Publishing, Chapter 31—A Model of Colour Vision for Practical Applications, and Chapter 32—Colour Reproduction Indices. The last two chapters make up the new Part V—Evaluating Colour Appearance.

Needless to say the model discussed in Chapter 31 is the Hunt model. Since I have been reading about the Hunt model for several years as it grew and was applied to

more and more situations, I particularly enjoyed having this complete overview summarize the model and the reasoning that went into each step of its development. The 55 pages of detail are more than is feasible to include in a single journal article.

In conclusion, this book still must be considered one of the required texts in any color library. Dr. Hunt's experience as both a researcher and a teacher are reflected in the text. Using his ability as a teacher, Dr. Hunt has made potentially very difficult topics quite readable. As a researcher personally involved throughout the years in many of the topics in this book, he brings the insight that leads the reader to a greater depth of understanding. I highly recommend this book to all those persons involved with color science.

ELLEN C. CARTER

Color Bytes, Blending the Art and Science of Color,
by Jean Bourges, Chromatics Press, Forest Hills, New York, 1997, 160 pp. \$34.95

People, such as consumers, with color vision may take "seeing color" for granted and never question how color perception works. Yet those who engage themselves in art and design may spend their lifetime trying to understand how color impacts their creative work. Still, those who involve themselves in modern color reproduction processes are constantly challenged to use the state-of-the-art digital imaging technology to render pictorial color images or match spot colors as dictated by the creative process. Ironically, those who are from the design side use very different language in describing color than those from the print production side.

The book, *Color Bytes*, strives to provide a basic understanding of the science and psychology of color, and to offer guidelines for color selections that yield harmony and pleasantness. The author, Jean Bourges, uses the Bourges Color Chart as a means to demonstrate how color design concepts can be fulfilled, and how these colors can be specified in terms of color names with which artists are comfortable and halftone dot sizes that printers understand in the reproduction process.

The Bourges Color Chart, developed by the author and her family, samples a printed color space using cyan, magenta, and yellow process inks and their tints. The chart consists of 20 columns representing hue variations. Each hue is numerically assigned with a color name, e.g., column 1 is known as mauve, column 2 as magenta, column 3 as crimson, etc. The chart also consists of 11 rows representing saturation variations of these hues. In process color printing terms, the 20 hues are reproduced by one-color or two-color combination using cyan, magenta, and yellow inks. And the 11 saturations are reproduced by halftone tints of different levels.

In order to blend the art and science of color together,

the author first uses the chart to divide all hues into four parts, and show how master artists' creative pieces and pleasing designs use each of the hues, shaded with various black, to create long-lasting impressions. Many full-page illustrations are used to stress the basic color design rule. For example, start a color scheme by choosing a dominant hue that reflects the mood, then support it with other hues. For example, if red is the dominant hue in the design, then the design and its message are highly charged. Likewise, yellow suggests energy; green symbolizes life; and blue is peace. The supporting hue is typically five hue steps apart from the dominant hue in the Bourges Color Chart. For example, mauve (column 1) and coral (column 6) form a pair in the warm color series suggesting bravery while grabbing the viewer's attention. On the other hand, teal (column 15) and purple (column 20) form a color pair in the cool color series revealing logic and reasoning.

Other than arranging the 20 hues linearly in a series, the Bourges Color Chart is also arranged in a circle to show the warm and cool hue divisions and the 10 complementary pairs. For example, the red/green complement will evoke celebration, and the yellow/blue complement can create tension. Again, many colorful illustrations were used to support the design concepts and related visual effects. Among them, the visual effect of simultaneous color contrast with the complements was nicely illustrated.

The author expands the color design rules by including the four-color harmony. To make the design more creative, and also color-coordinated, the magic lies in mixing two pairs of complements, one pair of warm colors (red and green), and the other pair cool (green and blue). From there, the interaction of these four hues can be tilted in many directions by adding tints, grays, and blends. The work of art, the Garden at Giverny, by Claude Monet was cited as an example of the four-color harmony.

As a faculty member teaching the technology side of color and its reproduction to students who major in art, design, and printing, I find this book useful and practical, because the book offers an artist's view of how colors bring visual impact to design. The book also uses a compact printed color chart (not thousands of colors, but 220 colors) to help readers visualize color and understand the relationships among various hues. It also bridges the gap between the creative process and the print production process. In addition, seeing how these simple design rules work in many of the colorful illustrations provided in the book is both convincing and a pleasant reading experience. I would like to take the opportunity to congratulate Jean for a job well done.

ROBERT CHUNG

COLOR BYTES, Blending the Art and Science of Color, Jean Bourges, Chromatics Press, Forest Hills, New York, 1997. 160 pp. Soft Cover \$34.95

COLOR BYTES is really three books: A Memoir; A Process Color Theory and System; and A Love Story.

First Book. The Memoir

Ms. Bourges introduces the reader to herself and her family on the inside front cover. Her education and experience in the world of art and color took her from convent school, cosmetics manufacturing, a tour in the U.S. Army Map Service, and full circle back to the family business. The family business was a highly respected and innovative engraving plant. Jean Bourges' unique family and experience in the field of color make her superbly qualified in her first book to present her ideas and philosophies in the story of color and colorants.

The introduction of *COLOR BYTES* defines color in the terms of natural phenomena and is a digested survey of the history of art from primeval man in the use of color in the caves of Lascaux, abstracted forms in masks and drawings, color in the Dark Ages used to instruct and tell stories, the illuminated documents of the Middle Ages, the Renaissance and the inventions and technology in pigments that gave us the "light" of Rembrandt, and the Enlightenment of the 19th Century impressionists. Ms. Bourges acknowledges and suggests a "New Color Renaissance" made possible by science and 20th Century technology that will reveal the mysteries and open even more doors for creativity and communication through the use of color.

The sections called, "Life With Color" and "100 Years of Separations" give the reader a history of a family involved with fine arts, photography, the development of dyes, and the task of engraving and printing at the turn of the century in New York City.

It was during this era that Albert Bourges, the author's father organized colors by numbers and developed the Bourges Color Notation System, which included opaquing pens and the Bourges Artists Shading Sheets that made the life of the engraver easier, much as the color computer aids today's graphic artist.

Ms. Bourges takes us on a sentimental journey to the Flatiron Building, exposes the pressures and tensions inherent in the Local Photoengravers' Union, and acquaints the reader with the talents and strength required of the men and women who created the first comic strips, posters, and magazine covers in full color.

Ms. Bourges tells the reader of the times of the wireless telegraph by Marconi, the photographs of Thomas Edison and Louis Lumiere, and the motion-picture camera. A man named Joseph Pulitzer installed a four-color rotary press, and William Kurtz created the first successful three-color photoengraving. Conde Nast did the color photography in their magazine and the Bourges family was there! These first sections of *COLOR BYTES* are fascinating reading, and I wish they had been even more detailed and extensive.

Second Book. A Process Color Theory and System

In Chapter One, the Bourges Color System divides the color world into four parts. Reds, Yellows, Greens, and Blues. Fire, Water, Earth, and Air. This seems simple indeed. It is easy to read what "scientists tell us," what "primitive cultures" mean by color association, what Aristotle and da Vinci "believed"; however, if footnotes and sources had been given to the reader I feel this section of *COLOR BYTES* would have more credibility and impact while providing a reference for further study.

The symbolic language of hue, as one of the color dimensions presented by Ms. Bourges, may very well be true in our Anglo-Saxon, North American culture; however, this symbology is not universal and can be limiting and stilted when presented in the printed word for all to accept and believe.

The study of the discipline of color symbology and response in humans must always be caged in the arena of beliefs, experiences, folk lore, and suppositions until that time when it is truly possible to definitively state that "red is passion," "yellow is ideas," "green is dependable," and "blue is peace."

These statements are empirical. However, other associations could be of red as succor, as in the Red Cross, yellow as the hue of cowardice, green as nausea, and blue as severe depression.

This reviewer does not out-of-hand disagree with "Bourges Divides Color into Four Parts" as presented or the associations imbued by Ms. Bourges, but I would have preferred this chapter be promulgated as one of individual experience and a sharing of ideas rather than as a statement of fact.

The other sections of this chapter, "Basics of Bourges" contain a series of short lessons designed to instruct the student of graphic art, give tips on color use, history of color phenomena, history of art and artists, and an introduction of how color data is communicated. This chapter, as all the other chapters, is very interesting to read and beautifully designed.

Chapter Three of *COLOR BYTES* gets to the meat of the book. Here Ms. Bourges repeats the Bourges Master Chart, but this time, with a phantasmagoria of color possibilities. The author extends the originally named four hues, red, yellow, green and blue to twenty hues by explaining tints and shades and blends. This chapter is a color manual where the "new Bourges color order base" is more extensively presented. At this point, the reader should refer back to Chapter One, where the author defines the Bourges Master Chart as one "Created in artists' terms and positioned with a digital data exchange. It is designed to be used and understood by students and professionals in both the art and technical worlds." Chapter Three is a useful tool for aid in color selection and communication with a client or a printer/engraver.

Any student of color, no matter whether graphic artist, fabric designer, interior designer, architect, fine artist, or

the practitioner seated at the color computer will benefit from the study of these color charts.

In Chapters Four, Five, and Six, Ms. Bourges discusses, in glowing terms the color qualities of warm and cool, complements, and color schemes that bring these qualities alive and singing with her text and selection of illustrations. The design of each page is impeccable, exciting and can't help but inspire a refreshed appreciation of the color that surrounds us.

Chapter Six is also divided into sections, (a), (b), (c), (d) and (e). (a) "Famous Color Circles" adds the previously linear Bourges System to historical color circles with very clear color complements. (b), (c), (d) and (e) are again a series of lessons in a conversational format between the experienced teacher and the student and contain ideas and suggestions on how to play with and have fun with color as a selling tool and a source of joy.

Book Three. A Love Story

In Chapter Two, Jean Bourges presents the Twenty Bourges Colors as many young parents talk about their children. It must become obvious, to even the most casual reader of this book, that the author of *COLOR BYTES* has a passion for color in all the dimensions that would be difficult to exceed.

Ms. Bourges weaves a story of each hue with its history, placement within the Bourges system, qualities, and uses from full saturation to the fairest of tints. Much as a parent will brag about "little Johnny's" win in yesterday's soccer game, his cracking his current spelling test, his kindness to his little sister and his sparkling personality and, of course, the brilliant future that surely lies ahead for him, Ms. Bourges talks about Mauve, Gold, and Ultramarine!

From pages 32–71 we are treated to color stories and images that please the senses and elevate the spirit. Again, however, the "story" of each hue would have been stronger if footnotes and references had been presented. For example, such statements as "Amber is the color of prosperity and wealth" are too broad and flatly one dimensional, leaving the other siblings in the "family" relatively unacknowledged.

Ms. Bourges "Position" of each hue within the Bourges Color System, of course, is accurate for this system and precise for recreating a specific hue in process inks.

The "Use" described for each of the twenty hues on a printed page is detailed and well thought out, representing many years of experience by the author in color selection and how the hue "will look" when used monochromatically or in combination with other hues.

Ms. Bourges presents a paragraph addressing the "Psychology" of each hue giving it almost human qualities. By the same token, any one who has worked with color knows that red is a "good spot" color, orange does seem to appeal to the appetite (note the 'Golden Arches') and yellow catches the eye when used with a complementary

or contrasting hue. Color does sell. It speaks to all in individual ways, and Ms. Bourges deserves credit for including these ideas for awareness and exploration by the student of color.

The Postscript of *COLOR BYTES* presents the twenty Bourges colors in a chart with their shades and tints and the accompanying CMY percentages required to communicate their duplication in process inks, a few more observations, anecdotes and "Production Notes." This section reports how this book was executed, and our color world would indeed be more accurate and beautiful if all books and color images would follow a similar formula.

COLOR BYTES is what it is about. The exquisitely beautiful color use by an enthusiastic, experienced, and knowledgeable worker in the color field gives joy and must stir the coals of the love of color in all who turn its pages.

MAGENTA YGLESIAS, ASID

The Munsell Color System: A Language for Color,
Joy Turner Luke, Fairchild Publications, New York,
1996. 127 pp. paperback

This text comes as part of **The New Munsell Student Color Set**. The text is new and a valuable addition to the Student Set. The Student Set is described in a new product announcement in another section of this journal. However, the quality and usefulness of the book necessitated extra attention in this separate book review.

It is obvious that the set is designed for students, and the text is also written for students, specifically art and design students. What may not be as obvious from the title is that the text goes well beyond introducing and familiarizing students with the Munsell color notation system. A very apt description of the text is found in its preface, "*The Munsell Color System: A Language for Color* stresses understanding what color really is and how human beings perceive it. This text includes a large amount of information, some of it fairly technical, that is necessary to work successfully with color in a world where artists and designers must deal with aspects of color that were handled by technicians in the past." [p. vii]

The ten chapters progress in an orderly development from the basic vocabulary of color, through the science of light, then color perception and relationships between colors, and finally closing with some of the confounding factors of color in industry. Also included is a glossary of selected terms from the American Society for Testing and Materials (ASTM) E 384, *Standard Terminology of Appearance*, the Paint/Coatings Dictionary, or those adopted by the International Commission on Illumination (CIE), sometimes with extra notes added, and a table of luminous reflectances for Munsell Values. All of this is accomplished in a very readable and elementary style that

will not frighten students whether they are from art, design, or more technically oriented disciplines.

Considering its length and proclaimed aim, the text is packed with lots of detail. In a book review in the last issue, the reviewer lamented that a demonstration of the visual blind spot was not included. . . well, you can find such a demonstration on page 46 of this book. Some of the topics one might be surprised to find in this text are details about vision including night vision, the stages of processing in human color vision and detail about some color anomalies of vision. Other difficult concepts such as metamerism are not avoided. One should read “the case of yellow and brown”, “the question of blue”, and “more about red”. Also, many of the concepts are developed with a strong historical sense, and references to artists other than Munsell abound—Chevreul, Signac, Rood, and Albers to name a few.

As much as the book is a nugget of accurate and useful color information, it is a tool to be used. At the end of each chapter, Luke has developed exercises to help the student make the concepts presented in the book so clear that they can be internalized. Thus, the concepts will become second nature, and will enhance rather than interfere with the artist’s or designer’s creative work. There are 36 exercises in total. The earlier ones involve arranging and rearranging the color chips provided in the Student Color Set to assure understanding of the dimensions of color, or other principles such as the effect of distance on perceived color. Others help students visualize color deficiencies or anomalies. Still other exercises relate the color chips to the actual colors and color variation found in the natural world or challenge the student to duplicate some of Albers effects of transparency with opaque colors. Finally, some of the exercises invite the student to paint, or create collages from printed materials, fabrics, or painted material that they have developed themselves to make works that drive home a specific point or principle.

Herein lies the broader value extending to all people interested in color including the color scientist, who already was familiar with the Munsell System. Working through the exercises (Yes, they are developed progressively enough that even scientists, like me, may dare to try a little artistic creation by the end of the book) will develop a fuller appreciation of color, and the vocabulary to communicate between the creative artists and scientists involved with color today.

ELLEN C. CARTER

Computer Graphics and Colorimetry, Color Systems, PostScript, Device-independent CIE Colors (Computergrafik und Farbmatrik), Klaus Richter, VDE Verlag, Berlin, 1996, 288 pp. & CD-ROM, in German, softcover, DM 120

The personal computer and its output devices have pro-

duced a whole range of new concerns having to do with color. The PC, properly configured, is an artistic, graphic, architectural, textile, photographic, etc., design tool. The problems occur when outputting the results of the design process in a medium other than the video display. This is where color science can make a contribution by applying its concepts and knowledge of color vision and color reproduction. The training of a new group of technologists in these concepts has been and continues to be an urgent task.

In Germany, this task has been addressed by the Bundesanstalt für Materialforschung und -prüfung (BAM). An extensive training program has been developed that introduces the participants to all aspects of color science that have a connection to color on video display and reproductions thereof. The book *Computergrafik und Farbmatrik* is a condensed record of such a training program. The book contains some 500 illustrations, most in color. They are also available on a CD-ROM in PostScript and PDF, where they can be updated and modified, if desirable, and printed out on foils or paper for training sessions. It also contains an Adobe Acrobat Reader, which makes possible inquiries in various directions.

In the introduction, Richter states that extensive research has been conducted at the BAM that relates high correlation visual evaluations of colored graphic materials with their colorimetric data. On that basis, the measured data can be used for the definition of an ISO-CIE quality index for input and output equipment.

Chapter 1 is a brief introduction into the technical concepts of color graphics, where reproduction is optimized using CIE colorimetry and its output data. The fundamentals of color and color vision are treated in Chapter 2, while Chapter 3 introduces CIE colorimetric values and color measurement.

The subject matter of Chapter 4 is special properties of color vision. Here Richter discusses color scaling and concludes on the basis of experimental data that, for larger hue differences, two cone absorption processes are jointly responsible; while, for the threshold differences only, the more sensitive of the two for the given color guides the difference perception. This requires two types of color space and transition formulae to get from one to the other. Richter then introduces various versions of chromaticity diagrams and shows their effect on uniform spacing of OSA-UCS and Munsell Hue data. Threshold data are presented in the form of MacAdam ellipses and as the result of Richter’s own extensive experiments. The black–white process is introduced as well as linear and logarithmic receptor sensitivity, leading to the formation of red/green and yellow/blue signals and their dependence on luminance. The historical line elements are discussed, and a double line element for thresholds is described that leads to a triple line element establishing the transition between steps and thresholds. The transition from colors on the video screen to colors on a substrate is also treated here.

Chapter 5 introduces reproduction techniques and their respective primary colors and discusses the rules govern-

ing each of the techniques: color television, color film, and three- and four-color printing. Chapter 6 then discusses the interface between color input and output devices in computer color technology. The European CEPT standard for color monitors, developed in 1983, is introduced, and the effect of film colors and scanner sensitivities is discussed. Chapter 7 deals with printing technologies, such as provided with matrix and laser printers.

The final Chapter 8 has the title "PostScript and CIE Color Spaces." It introduces Adobe System's PostScript language, which offers a device-independent treatment of color using CIE colorimetric data. Examples of programs to achieve various color and black raster types are listed. CIE-based color space transformations for the European and U.S. television standards are explicitly presented, and information is given on how to optimize color reproduction using a series of CIE-defined test colors.

A reference section lists 16 book texts and a range of CIE, DIN, and Swedish standards as well as specific PostScript literature. Finally, there are two exercises. The first involves the calculation of tristimulus values of optimal colors, the second the plotting in a chromaticity diagram of the basic colors of a hue circle as well as of the primary and mixed colors of various color reproduction systems.

The readership for the text is listed as technical experts, engineers, scientists, and designers in color-related fields, as well as teachers and students in schools with specialized courses in the field.

The book, in this reviewer's opinion, is primarily suited as a reference for training received or as a source for training materials. Its density makes it less suitable as a text to learn from. For the expert, it summarizes a broad amount of information in the color field, at times with a particular slant. It addresses a very topical subject in a form that is, to the best knowledge of the reviewer, not available in this form in the English language.

R. G. KUEHNI

Color Cognition in Mesoamerica, Constructing Categories and Vantages by Robert E. MacLaury, University of Texas Press, Austin (1997), 592 pp. \$85.00 hardcover

The heart of this book is an account of MacLaury's epic study of the colour categories of some hundred languages of Mexico and Central America. In addition, he proposes a theory of the origin and development of colour categories in the individual, which can then gain cultural expression within the language. The work was heavily influenced by Berlin and Kay's (1969) seminal monograph, and by others in the remarkable cluster of people from a range of disciplines at Berkeley: Lakoff (Linguistics); Rosch-Heider and Palmer (Psychology); and De Valois (Neuro-Physiology). MacLaury acknowledges these early

influences, but his theory and his methods have increasingly diverged from Berlin and Kay.

There is a very useful chapter on the history of the debate over cultural relativism vs. universalism of colour categories (Chapter 2). This includes an account of how MacLaury's theory of categorization developed over the ten or fifteen years of field work and of the impact of Berlin & Kay's on the psychologist Rosch-Heider.

MacLaury's methods are based on intensive "interviews" with individual informants. During the interview, informants are asked about colour terms in their language (usually by a native speaker) and then asked to map the range of each term by placing a grain of rice on each exemplar in a fixed array of 330 Munsell colours. When an informant stops, they are asked if there are more examples, and so on, until the informant insists there are no more instances. The best example of each term is also determined through questioning.

The field studies found that the relationship between colour categories could be qualitatively different to the that among classic "Aristotelian" categories. For instance, some pairs of categories had "coextensive ranges" although neither was subsumed in the other. Although the mappings of such coextensive categories started from different points, the final maps of two categories were more or less identical. In fact, he describes a whole set of empirical relationships between pairs of colour categories.

Vantage theory is a model of the development of colour categories based on a spatial analogy with terrestrial views from different vantages. In combination with the proposal that as societies become more complex there is a shift from attending to similarities to attending to differences, the theory is intended as an account of the evolution of colour categories, and as such is an alternative to Kay and McDaniel's (1978) theory. Part of the proposal is that languages with few colour terms tend to have categories based on brightness (e.g., warm and cool categories), but during evolution, categories based on hue tend to emerge. Although most language trajectories follow sequences more or less in accord with Berlin and Kay (1969), many other trajectories are possible, and MacLaury attempts to reconstruct many of these based on the cross-sectional data from his field work.

Overall the book is useful, and will be of interest to people from many disciplines. I was, however, left with two main reservations. First, to what extent is the discovery of unusual colour category relationships, such as coextensive ranges, a function of the rice mapping method? It would be reassuring to see the same pattern emerge, without the repeated prompting from the experimenter, and with naming based on random presentation of single chips. Second, are there testable predictions that follow from vantage theory? The theory was fitted to the data, more or less *post hoc*, and, therefore, deriving potentially refutable predictions from it is a necessary next step.

IAN DAVIES

Sensory Qualities, by Austen Clark, Oxford, New York, 1996, paperback \$19.95

In the introduction to his recent *Sensory Qualities*, Austen Clark raises the question, “Why are sensory qualities so troublesome?”

In reply, he writes:

The world as described by natural science has no obvious place for colours, tastes, or smells. Problems with sensory qualities have been philosophically and scientifically troublesome since ancient times, and in modern form at least since Galileo in 1623 identified some sensory qualities as characterizing nothing real in the objects themselves. . .

The qualities of size, figure (or shape), number, and motion are for Galileo the only real properties of objects. All other qualities revealed in sense perception—colours, tastes, odors, sounds, and so on—exist only in the sensitive body, and do not qualify anything in the objects themselves. They are the effects of the primary qualities of things on the senses. Without the living animal sensing such things, these “secondary” qualities (to use the term introduced by Locke) would not exist.

Much of modern philosophy has evolved from this fateful distinction. While it was undoubtedly helpful to the physical sciences to make the mind into a sort of dustbin into which one could sweep the troublesome sensory qualities, this stratagem created difficulties for later attempts to arrive at some scientific understanding of the mind. In particular, the stratagem cannot be reapplied when one goes on to explain sensation and perception. If physics cannot explain secondary qualities, then it seems that any science that can explain secondary qualities must appeal to explanatory principles distinct from those of physics. Thus are born various dualisms.¹

Just so. Now, everyone familiar with Burt², Duhem,³ Lovejoy,⁴ or Lockwood⁵ knows all about Locke’s division of the primary from the secondary, but Clark sums up the situation beautifully, covering a good deal of ground in a few succinct paragraphs. A bit later on, he plumbs the fissure at the foundations of our science:

Contemporary materialists are still wrestling with this issue, which in many ways seems just as intractable as it did in Hobbes’s time. Although we now know much more about how the nervous system works, it still seems impossible to explain the qualitative character of sensory states. An apparently unbridgeable gap yawns open between the qualities presented by sense and any possible physical explanation. . .

The problem might be described as follows. For the

materialist, mental states are identical with physical states of the brain. . . . A system of neurones has enormously complex patterns of electro-chemical activity. Voltage differences across the membranes of its neurones are a function of the electrical activity of thousands of other neurones, each of which in turn reflects activity in thousands of its neighbors. Now the materialist proposes to identify sensory process with some of these events, and the obvious question is, “How could any of that ever add up to a sensation?”⁶

History Teaches Us

Clark’s question is, of course, the celebrated “hard problem” met with everywhere in contemporary arguments regarding a science of consciousness. Clark is unusual here in that he has done his homework—he has not only assimilated the canons of psychophysics, but has also gone where many scientists fear—deep into the metaphysics of their subject.

As Crick and Koch⁷ have noted recently, the entire business of mind and consciousness was, until just the other day, considered “too philosophical” to merit the attention of scientists—though with a few notable exceptions. We think of Einstein, e.g., who quotes with approval an admitted philosopher in his “Remarks on Bertrand Russell’s Theory of Knowledge,”:

We think that grass is green, that stones are hard, and that snow is cold. But physics assures us that the greenness of grass, the hardness of stones, and the coldness of snow are not the greenness, hardness, and coldness that we know in our own experience, but something very different. The observer, when he seems to himself to be observing a stone, is really, if physics is to be believed, observing the effects of the stone upon himself.⁸

Is physics always to be believed? In a terrific little work by Schroedinger, a physicist of some note, we find the following passage:

If you ask a physicist what is his idea of yellow light, he will tell you that it is transversal electromagnetic waves of wavelength in the neighborhood of 590 millimicrons. If you ask him: But where does yellow come in? he will say: In my picture not at all, but these kinds of vibrations, when they hit the retina of a healthy eye, give the person whose eye it is the sensation of yellow.⁹

Oddly enough, while it is often claimed that Schroedinger’s equation contains all that can be known about a thing, we have here the author of that equation telling us in plain language that physics has no place for the color of a thing. So peculiar a state of affairs would seem odder

still if we were to attend to Mach,¹⁰ where he says: “A color is a physical object as soon as we consider its dependence, for instance, upon its luminous source, upon temperatures, upon spaces, and so forth.”

Hermann Weyl, unarguably one of the finest scientific minds of record, did not shrink from difficulties:

The processes on the retina produce excitations which are conducted to the brain in the optic nerves, maybe in the form of electric currents. Even here we are still in the real sphere. But between the physical processes which are released in the terminal organ of the nervous conductors in the central brain and the image which thereupon appears to the perceiving subject, there gapes a hiatus, an abyss which no realistic conception of the world can span. It is the transition from the world of being to the world of appearing image or of consciousness.¹¹

Weyl writes of a world of *being* and a world of *image* or *consciousness*—and this crucial (though often unconscious) distinction remains our legacy of that venerable duality of mind and matter that we freely associate with the name of Descartes—but who was largely cashing in on what Galileo was on about just now regarding which properties of things are “real” and which properties exist “only in the mind.”

The Heart of Light

Professor Clark makes a compelling case for the contributions of psychophysics to a genuinely scientific understanding of color and the other “secondary” qualities. He writes clearly, with quiet elegance, at times displaying a mathematician’s precision, as when he explains what we ought to mean when we use words like “qualia” or “quality”:

Sensation and perception have as necessary conditions the occurrence of various internal states of the subject. The subject senses or perceives objects in virtue of having those states, and would not sense or perceive those objects if those states were not present. Call such states ‘sensory’ states. They have a specific character, and it is in part because they have the character they do that one perceives just what one does. Let us define the ‘qualitative’ character of such states as those qualities that determine exactly how the world appears. Intuitively, if later the subject has an experience with exactly the same qualitative character, then it will seem to the subject that he or she is perceiving exactly the same objects. Sensory qualities are those qualities of sensory states that account for this appearance.¹²

Reason and definition, however lucid, cannot be regarded as thoroughly scientific until they come to terms with experiment, with prediction, mathematics, and temperate prose. Here again, Clark does not disappoint. Thoroughly grounded in methodology, he knows an important result when he sees one: “. . . we should here flag a remarkable scientific achievement: if we know the absorption spectra for receptors of a particular individual, we can quantify that individual’s wavelength mixture space and predict exactly which combinations of wavelengths that individual will find to match under laboratory conditions.”¹³

This is indeed a remarkable achievement, one we might expect to occupy a lofty position in future histories of scientific discovery. For again, colors have long been “known” to exist “only” in the mind . . . if only in the minds of scientists. Yet now we are able to predict what “physical” wavelengths of light will reliably produce what “mental” colors.

The yawning abyss between mind and matter would appear to have been bridged.

Experimental fact, regular and reproducible, joins hands with a *symmetry*, an invariant aspect of nature—such as was formulated by Helmholtz, with classic simplicity: “Similar light, under similar conditions, produces a similar sensation of color.”¹⁴

With this crucial enlargement and generalization: We can now quantify matters. It would not overstate the case (falling back on a familiar dualism) to say that we now have a “physical” means whereby we can predict the observation or perception of “mental” colors—and so, a reasonable basis for a genuine science of consciousness.

BRIAN FLANAGAN

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