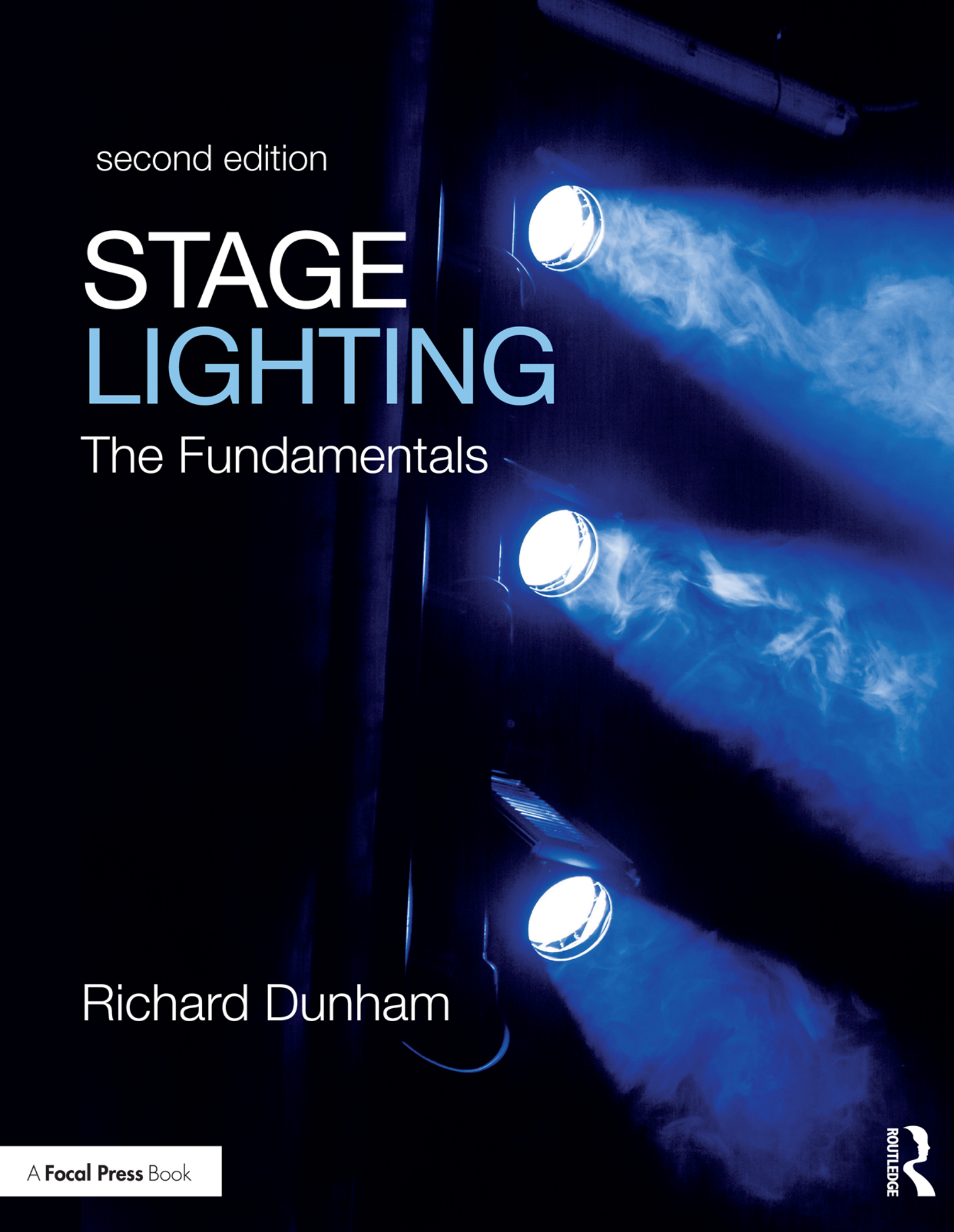

second edition

STAGE LIGHTING

The Fundamentals

Richard Dunham

A **Focal Press** Book

ROUTLEDGE

STAGE LIGHTING

Stage Lighting: The Fundamentals is written specifically for introductory stage lighting courses. The book begins with an examination of the nature of light, perception, and color, then leads into a conversation of stage lighting equipment and technicians. Lamps, luminaries, controls/dimming, and electricity form the basis of these chapters. The book also provides a detailed explanation and overview of the lighting design process for the theatre and several other traditional forms of entertainment. Finally, the book explores a variety of additional areas where lighting designers and technicians can find related future employment, such as concert and corporate lighting, themed design, architectural and landscape lighting, and computer animation.

New for this edition:

- enlarged full-color illustrations, photographs, light plots and examples of lighting design;
- updated information on LED lighting and equipment;
- expanded discussion of the practical use of color as a designer;
- expanded discussion of psychological/perceptual effects of color;
- new discussion of color mixing through light sources that make use of additive mixing;
- expanded discussion of industry professions;
- expanded discussion and illustrations relating to photometrics;
- expanded discussion and examples of control protocols and new equipment; and
- updated designer profiles along with the addition of still more designer profiles.

Richard Dunham is a scenic and lighting designer as well as a professor and head of design at the University of Georgia. He is a United States Institute for Theatre Technology (USITT) Fellow and former lighting commissioner from 1998 to 2006. His professional credits include numerous productions throughout the East Coast, New York City, and the Midwest, as well as being Lighting Certified (LC) and a member of Illuminating Engineering Society of North America (IESNA) and associate member of the International Association of Lighting Designers (IALD).

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STAGE LIGHTING

The Fundamentals

SECOND EDITION

RICHARD DUNHAM

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PREFACE

IT IS IMPORTANT to note that *Stage Lighting: The Fundamentals* is the first of a two-part companion set of lighting design books, the second book being *Stage Lighting: Design Applications and More*. The chapters that form the basis for the material presented in this book are based on the printed segment of the first edition (*Stage Lighting: Fundamentals and Applications*) while the chapters on more specialized applications that were previously presented online in the first edition are now in print in the second book (*Stage Lighting: Design Applications and More*). This book, *Stage Lighting: The Fundamentals*, is focused primarily on materials typically found in introductory to intermediate courses, while *Stage Lighting: Design Applications and More* is focused on a variety of specialized lighting applications that are more characteristic of topics presented in more advanced lighting classes. That book may also be used by more advanced readers as a personal reference. Both books have also been updated with new materials to reflect current trends in the industry and are now printed in color. Regardless of the reader's level of lighting expertise, they will most likely find materials that speak to their interests and needs in both books.

Before going any further, I want to express my continued thanks to the many instructors and colleagues who have made the first edition of the book so successful. More importantly, I'm thankful for the conversations and suggestions we have had that aided me in making improvements in this second edition. Focal Press/Routledge–Taylor & Francis Group reflects a new partnership that I feel will allow the book to continue to grow in both popularity and usefulness to students and future lighting designers. In addition to updating, the most significant changes between the first and second editions relate to moving the former online chapters into a second volume and printing both books in color. This also allowed me to move *Stage Lighting: The Fundamentals* towards more introductory materials while shifting some of the more advanced concepts to the applications topics in the second book. Several additional upgrades and revisions provided in the second edition of both books include the following: printing the majority of the images and figures in full color, updating a number of technology sections to reflect current trends and equipment (especially in the area of LEDs, which are overtaking the lighting industry), updating several design processes (i.e., significant changes have been made in the recommended practices of architectural lighting since the printing of the first edition), reorganization and consolidation of several topics to fit the manner in which instructors are using the book, additions to the books' resources (glossary, bibliography, manufacturer contacts, and periodical listings), and the inclusion of nearly a dozen additional professional profiles that provide introductions to lighting professionals who aren't necessarily designers but who represent other avenues of employment for future lighting specialists (along with updates to the majority of the designer profiles that appeared in the first edition).

Lighting design is one of the most influential design specializations existing in today's society. Light gives us the primary means by which we sense our environment. It plays a fundamental role in our perception of the world and how we observe it. Light can hide or reveal an object and its features, modify the perceived shape of an object, suggest motion, distort or enhance an object's colors or texture, and can be used to create or alter moods. These are only a few of the many ways that light can manipulate our perception of the world. This book has been written primarily for the beginning to intermediate level student. While a certain amount of technology must be understood before moving on to concepts involving design, the majority of this book is focused on the design process. Other topics presented in this volume are based primarily on theatrical lighting and include the properties of light, effects of lighting, the control and manipulation of light, theatrical lighting equipment, designing for traditional forms of entertainment, projection, and a brief introduction to a variety of lighting applications beyond theatrical lighting. Although it is assumed that this and its partner book will be used primarily in theatrical lighting classes, the books should also be useful to those in the electrical engineering and architectural or interior design lighting fields as well. The books speak to a broader audience—one that is seeking the fundamentals of lighting regardless of lighting discipline and where we are encouraged to crossover between the many lighting specialties.

I believe that the future of lighting design lies in a designer's ability to understand and deliver designs in light—period. Whether designing for an opera or a building, the basic principles of lighting hold true despite the differences in equipment and specific design applications that exist between the disciplines. Many theatrical designers already move naturally among any number of genres of entertainment lighting—and while most were trained predominantly in theatrical design, there is immense potential for designing in a number of additional areas of lighting as well. Likewise, designers with an electrical engineering background are bringing more theatrical elements into their designs as well. All you need to succeed can be found in a positive attitude in making the shift, becoming familiar with the equipment and practices of the specialty, looking for opportunities to observe and learn a new discipline, and being able to modify your techniques in order to suit the new avenue of design. Regardless of individual preferences, more and more lighting designers are finding themselves crossing back and forth among a variety of lighting applications as a means of maintaining a successful career. As an added benefit, these additional areas of lighting also frequently offer larger design fees and other incentives for a project (such as permanence) that many theatrical organizations or projects cannot provide.

The theme of both books lies in providing a link between many of these lighting disciplines. While there is a solid introduction to theatrical lighting design (especially design process) in this book, it is my hope that you can use both books as references that focus on lighting design and the design methodology that connects these fields rather than simply focusing on the equipment and technological emphasis that are characteristic of many lighting books. The topic of crossover to this degree had not really been attempted in a lighting text before the first edition of this text. Additionally, a detailed discussion of the design process spans several chapters and forms another critical element of this book. While the book outlines a reasonably specific process, it should not be thought of as the only process. It is simply a place for the beginner to receive fairly detailed instructions that can then be tweaked as their skills and processes evolve. In keeping with the more universal applications of lighting, a variety of specific lighting disciplines are introduced in Chapter 16. Many of these are presented in considerable detail and as individual chapters in *Stage Lighting: Design Applications and More*. Those chapters focus on essential design issues and equipment differences that are unique to working in a variety of different areas of lighting design. Questions relating to special considerations, luminaires, control and equipment needs, and design concerns that are characteristic of a particular lighting specialty are also raised in those chapters. While technology cannot be avoided, it's been my goal to present the technical material as it becomes relevant and best pertains to the design needs of a "total" lighting designer. Because equipment is constantly in a state of evolution, I have chosen to dedicate many figures to illustrations that present design concepts rather than the traditional photographs of lighting equipment and production shots. Instead, in order to remain current, I provide an appendix with a listing of lighting equipment manufacturers along with a link to their websites, where up-to-date product information is always available.

Finally, the most important element of both books is to simply demonstrate the profound effect that light and a lighting designer can have on our lives. My hope is that not only can I provide the spark of inspiration that will allow readers to have a deeper appreciation of the art and tools of lighting, but also that these books will equip them with enough information to use these tools to develop effective art while "painting with light."

ACKNOWLEDGMENTS

AS WITH ANYTHING of this magnitude, there are many people who have provided help in producing this project. You don't have to work very long in this business to discover that many professionals in our line of work are truly giving and willing to share their knowledge and experiences freely. This extends from the designers who have worked on common projects with me, to fellow educators, to the Tony Award nominees and winners who form the mainstay of Broadway lighting design. Colleagues who have been using the first edition of the book have also been a great source of suggestions as we have worked on the second edition of this project. Additionally, our equipment manufacturers and professional organizations are another group of contributors who are truly interested in sharing their expertise and knowledge with us as well. It is impossible to mention every one of them here, but there are a number of individuals that deserve a special mention and thank you. First, my editors and the rest of the staff at Focal Press/Routledge and Taylor & Francis Group: Stacey Walker (acquisitions editor, who first approached me regarding the second edition) and Meredith Darnell (editorial assistant) and Lucia Accorsi (editorial assistant) who have kept this project on track since we first began to work on the second edition nearly three years ago. Also, to my initial editors and staff at Pearson Education/Allyn & Bacon who brought the first edition of the book to life. I am most appreciative of all of these individuals and their helpful suggestions as we have gone through the process of producing both editions of the books. I also want to thank all of the designers and manufacturers who shared materials with me or who were kind enough to be interviewed and let me feature them in the sidebars. These are among some of the busiest people in the business and I appreciate their willingness to share their knowledge with the next generation of lighting designers. Also, I want to thank the many students that I have had the pleasure of teaching, and in some cases learning from, over the 30-plus years that I have been involved in lighting education. Nobody is an expert in all areas, and the breadth of these books makes this an even more relevant issue. This is especially important for those topics that are featured in *Stage Lighting: Design Applications and More*—and to that point I enlisted several colleagues and friends who graciously read and offered comments and corrections on materials I have presented on various specialty areas of the lighting industry. Many, but not all, of these individuals are featured in the sidebars, but to make sure that none are missed I want to publicly acknowledge and thank the following individuals for their support and comments: Marilyn Lowey, Jim Moody and Jeff Ravitz (concert and spectacle lighting), Bill Klages, (film and television lighting), Bob Shook and the late Bill Warfel (display, landscape, and architectural lighting), Tom Ruzika (themed/specialty design), and finally Mike Hussey and John Kundert-Gibbs (virtual lighting). These folks are all at the top of their respective specialties. I also want to thank those colleagues who reviewed portions of the manuscript as I went through the revision/updating process; I am appreciative of the comments and suggestions that came from these individuals for both editions of the books. It's difficult to be a sole writer on a project as large as this, and the books are much improved through the comments and input that I received from all of these individuals. Finally, as in the first edition, a very special thank you to my family (my very supportive wife, Joelle and our children, Chelsea, and Richy) as well as our many friends and extended family who once again had to deal with the fact that "the books" were always somewhere in my list of priorities over the last several years.

Richard Dunham, Spring 2018

ABOUT THE AUTHOR

Richard E. Dunham, LC, IESNA (professor and head of design at the University of Georgia) has been involved in lighting design for close to 40 years—more than 30 in lighting education. He has hundreds of design credits in both academic and professional lighting/scenic design with credits in drama, dance, musical theatre, opera, concert/music festivals, and various architectural projects. Several lighting credits include designing for the Brunswick Music Theatre (Maine State Music Theatre), Music Theatre North, Springer Opera House, Atlanta Lyric Theatre, and many New York metropolitan and Off/Off-Off Broadway productions with companies like Broadhollow Theatres, The Circle Repertory Lab, and Jean Cocteau Repertory Theatres. He is a USITT Fellow, and has served on the board of directors and has been active in the leadership of the lighting commission of USITT for many years—most notably as lighting co-commissioner from 1998 to 2006. He is a frequent presenter at conferences and has authored articles on theatre design and technology, edited the second edition of *Practical Projects for Teaching Lighting Design: A Compendium*, was on the editorial committee of the second volume of the compendium that was published in 2016, and has won two Herbert D. Greggs Honor Awards for his articles. He also coordinated the latest revision of the *RP-2 Recommended Practice for Lighting Design Graphics* (2006). In architectural lighting, he holds the LC certification granted by the National Council for Qualifications for the Lighting Profession (NCQLP) and is a member of IESNA and an associate member of IALD. He can be contacted through his website (rdunhamdesigns.com).

PART ONE

LIGHT: THE MEDIUM

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CHAPTER 1

THE NATURE OF LIGHT

BEFORE YOU CAN learn to design with light it is important to gain a basic understanding of the nature of light. Unlike other areas of design, light isn't tangible: it appears to be mysterious and can cause unpredictable results, yet it has an impact on everything it touches. Light is controlled in ways that require at least some understanding of optics and electricity—topics that easily intimidate many people. As lighting designers, light itself is our medium, and we can usually convey our design ideas only through indirect methods such as with pencils, paints, or computer simulations. This is very different when compared to other artistic disciplines where the media are tangible. You can't easily draw or render light as you would in a rendering of a scenic or costume design or with a sketch of a building, where a viewer can easily gain an understanding of a structure and color schemes that are created by a designer. The effects of light are in many ways a mystery until the lights are turned on and a subject is illuminated. Because of this, it is important to develop an understanding of the actual medium of light. What is it? How does it behave? How might we control it? What is its effect on other objects? With experience, you can predict many of the answers to these questions, but even then, you can't be completely sure of your design choices until you see them actually revealed in light.

In this chapter I examine the physical properties of light, its makeup, and how it moves through space. I will also provide you with several methods that we use to describe light. Finally, I examine how light functions within our daily lives. These fundamental principles hold true not only in lighting dramas and other entertainment programs, but also for lighting buildings and natural settings where the sun and other light sources can be observed.

What is Light?

Quite simply, light is a form of energy. Specifically, it is a form of radiant energy that is associated with a given portion of the **electromagnetic spectrum.** Radiant energy is a form of energy given off by radiant bodies (heat/light sources) such as stars, like our sun. Radiant energy moves away from its source at a constant speed while light is but one form of radiant energy which has a speed of 186,000 miles/second. Most of us know this as the "speed of light."

The Electromagnetic Spectrum

The electromagnetic spectrum represents all forms of radiant energy. Some researchers identify the electromagnetic spectrum with a particle-based theory while others refer to a wave-theory approach. Regardless of the theory, the general principles are the same. In each case, energy is thought to pulsate outward from a source at the speed of light in oscillations that create a wavelike effect and form patterns that can be measured. In fact, the variables that we generally use to describe radiant energy are based on wave theory. Most commonly we make distinctions between different forms of radiant energy through measurements of either **frequency** (***f***) or **wavelength** (**λ**). Wavelength is the distance between similar points in a waveform over the time that a wave completes one cycle, while frequency refers to the number of oscillations or cycles that a waveform completes over a given time. These variables

are inversely proportional to one another: as frequency increases, the wavelength gets shorter, or as frequency decreases, the wavelength gets longer. The strength or amplitude of the waves is commonly called the **intensity (I).** In visible light we often refer to this as the brightness of the light. Figure 1.1 illustrates the relationship between intensity, frequency, and wavelength.

In lighting, we generally use a measurement of wavelength to make a distinction between different types of light. The range of wavelengths produced by radiant sources is extreme. At one end of the electromagnetic spectrum we find electrical waves with wavelengths measured in miles. The 60-cycle electrical currents that are used in our homes may have a wavelength of more than 3,000 miles. Many other forms of **electromagnetic radiation (ER)** are associated with wavelengths so small that a special unit, the **angstrom (Å)**, has been introduced to measure them. One angstrom is equal to 1/254,000,000 of an inch. At the opposite end of the electromagnetic spectrum from electricity are cosmic rays, which may have wavelengths as small as 1/10,000 Å. The electromagnetic spectrum is a collection of different types of radiant energy that can be specified through their varied wavelengths.

The Visible Spectrum

What concerns us as lighting designers is a very limited range of wavelengths contained within the electromagnetic spectrum that we commonly refer to as the **visible spectrum.** This is a collection of wavelengths that can be sensed by the human eye. Those energy forms that lie outside of our perception with wavelengths that are longer than we can sense include infrared, radar, television and radio waves (with increasingly longer wavelengths). Energy forms with progressively shorter wavelengths that also lie outside the realm of our visibility include ultraviolet, x-ray, gamma and cosmic rays. Figure 1.2 illustrates the relationship between wavelength and the individual classifications of energy that make up the electromagnetic spectrum.

The visible spectrum can be further broken down into smaller components representing individual colors—each color representing a specific wavelength of radiant energy. We have all witnessed the rainbow effect produced through the refraction and separation of light into these individual colors by a prism, a storm cloud, or water spray from a hose or fountain. Every color represents light of a different wavelength or frequency. The range of wavelengths generally found within the visible spectrum extends from approximately 400 (violet) to 700 (red) nanometers. A nanometer is one-billionth of a meter. A second manner of expressing wavelength has already been introduced through the measurement known as an angstrom. An angstrom is 1/10 of a nanometer. In this case, the visible spectrum would be expressed as having wavelengths in the approximate range of 4,000–7,000 Å.

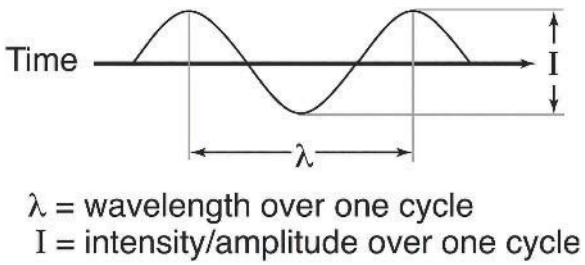

Figure 1.1a Wave relationships. a. Relationship of intensity (I), wavelength (λ), and cycle or frequency (*f*)

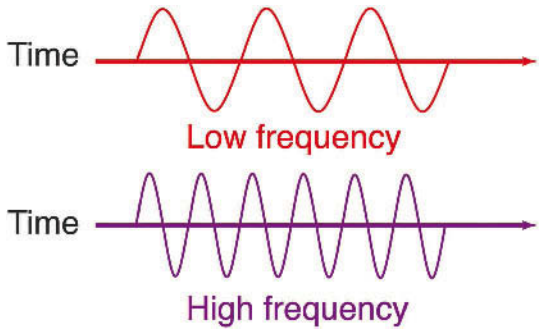

Figure 1.1b Frequency (*f*) and wavelength (λ) are inversely proportional

The Eye and Seeing

Our observation of the world around us is based solely on the manner in which we sense our environment. We can't directly observe anything without the aid of various senses. If you think back to a basic biology class you will probably remember that the human body is equipped with five sensory devices. The senses that these manage include sound, touch, smell, taste, and sight. Each sense consists of a series of sensory organs that convert physical phenomena into nervous impulses that our brains process in a way that helps us to observe the world around us. Our skin allows us to feel, our ears allow us to hear, and our eyes allow us to see.

The visible spectrum represents the range of wavelengths to which the human eye can sense light. If we were sensitive to light relating to a different range of wavelengths, our visible spectrum would shift to a different portion of the electromagnetic spectrum. An infrared camera, such as the ones used in defense or security systems, is sensitive to a different portion of the electromagnetic spectrum than the human eye. Hence, in a situation such as a dark night where we cannot see the movements of people like prowlers or soldiers, the camera is able to "see" for us.

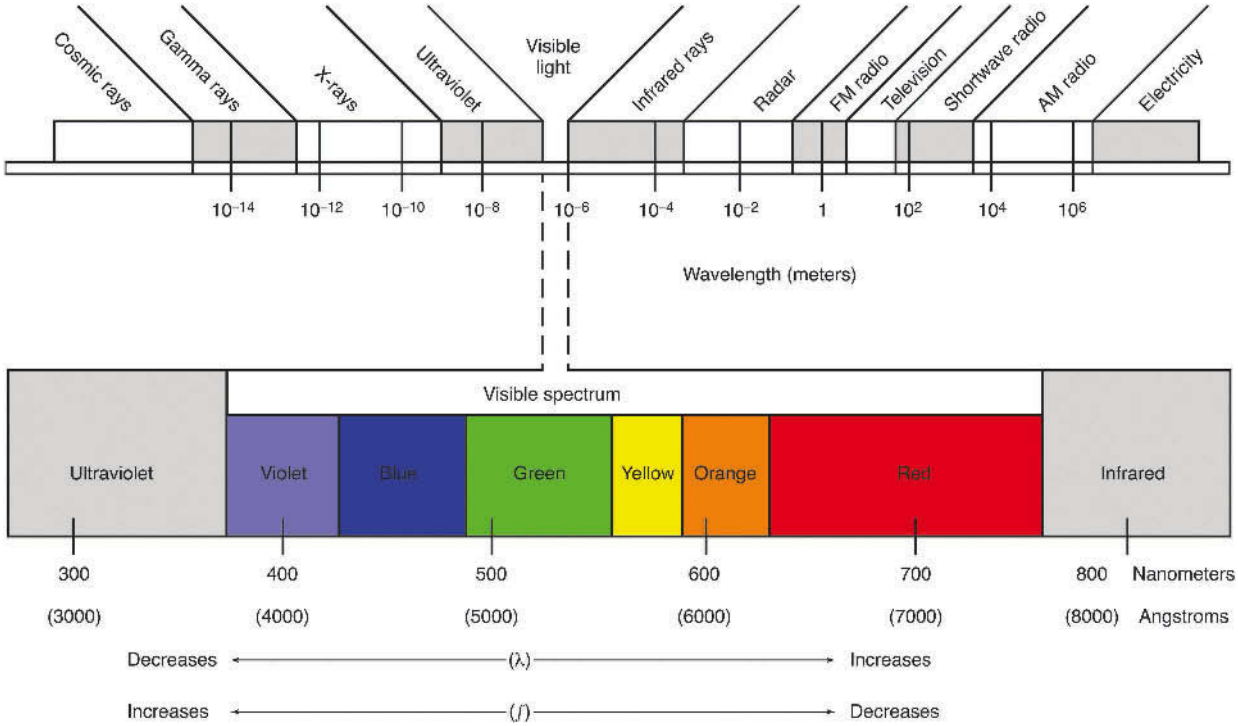

Figure 1.2 The electromagnetic and visible spectrums

The Controllable Qualities of Light

It is important at this point to introduce a vocabulary that enables us to define and describe light. One of the most difficult tasks for a lighting designer is in describing the lighting envisioned for a project. Light is our medium and it cannot be illustrated effectively through an indirect means such as with a model or rendering. A scenic designer can illustrate to a reasonable degree of success a final design and color palette for a project through the use of markers, pencils, or paints. Likewise, in addition to renderings, a costumer can present swatches or scraps of fabric to indicate the materials from which a costume will be created. This isn't so with a lighting design, where light itself is the medium and where nobody can get a true sense of the outcome of a design until the actual lights **(luminaires)** are placed in the performance space, colored, and balanced through setting specific brightness levels for each light. Because of this, several descriptive qualities have been defined to help us communicate with one another about light. These are generally not thought of in terms of quantitative elements but are used instead to help us set up a comparison between various lights and lighting effects. While absolutes may come into the discussion, most of these qualities are used solely within a descriptive or comparative basis. These qualities are also universal and can be translated to any field of lighting, whether working in traditional theatre or lighting an office tower, garden, or the latest Rolling Stones tour. While there may be slight variations in terminology between lighting disciplines, most designers have come to refer to four primary qualities for describing light. Any light, no matter how produced or modified can be described through these four attributes. The variation of any one of these qualities will make a distinction between any given example of light. These qualities include **intensity, distribution, color,** and **movement.** As a whole, these are essentially the same qualities that Stanley McCandless described in 1932 when he first wrote *A Method of Lighting the Stage*.

Intensity

The most easily described quality of light is intensity, which refers to the brightness of the light. While it might be described very specifically and can be evaluated through measurements such as the candela or footcandle, it is more often described through a comparative basis. "This light is brighter than that light," "this light is approximately half the intensity of another light," or "that light is as bright as the moon" are examples of this type of comparison. The human eye can perceive light at an extreme range of intensities. In World War II, soldiers learned that a German scout plane nicknamed "Bed Check Charlie" could see the tip of a lit cigarette from several miles away. If they were spotted, soldiers could anticipate a visit from a bomber sometime later

that night. At the other extreme, the intensity of a light can be so bright that it becomes harmful and could even cause damage to our eyes. Examples of this would include looking directly into the sun or being exposed to the bright light that accompanies welders as they strike an arc. In most theatrical venues we are generally concerned only with the relative appearance of the light and whether there is enough visibility to see what has to be seen at any given moment on the stage. In video and film lighting, the intensity isn't as flexible, and there is a minimum threshold of intensity that a **director of photography** must provide to maintain a proper exposure for a setting. We have all taken photographs of last Friday night's party or some other special event to find that the results that our phone or camera captured produced only shadowy silhouettes that we think we recognize as our friends. Even with today's mobile phone cameras we often find that images can suffer from poor lighting and are either under or overexposed. Architectural lighting designers speak of a minimum amount of illumination for a given **visual task** or job. These tasks require a minimum number of **footcandles** or **lumens** of illumination. For example, the lighting levels required for a personal home are much lower than those needed at a retirement home, where elderly residents often have trouble seeing, while a meeting room requires higher intensity levels than a restaurant seating area—although none of these settings would require the illumination levels needed for an assembly line producing high-tech products. Regardless of whether describing a specific level of illumination (i.e., footcandles) or simply describing intensity on a comparative basis, intensity becomes one of the most important ways of helping us distinguish between different types of light and lighting.

Another important element of intensity relates to the principle whereby the intensity of a light drops off dramatically as the distance from the source is increased. This is expressed through a concept/formula known as the **Inverse Square Law.** This law will be presented in more detail in Chapter 7, but simply states that the illuminance of a light source is inversely proportional to the square of the distance from the source. A quick examination of this principle can be demonstrated by playing a flashlight on a wall and noting the apparent brightness and coverage of the light while varying the distance that the flashlight is held from the wall.

Distribution

The second controllable quality of light is known as distribution. McCandless described this as "form." Most lighting designers relate distribution to two specific properties of light: angle (or direction) and quality.

Angle refers to the direction from which the light is coming. Where are you hanging the light source? How does it play upon the subject? Where are the highlights? Where do the shadows fall? A light coming from behind the subject presents a completely different image and associated mood than a light coming from in front of the subject. A couple walking hand-in-hand into a sunset presents a much more dramatic image than if the sun were directly overhead. Dracula would most likely not appear so scary if we chose to light him in any other way than through a silhouette. The angle of the light helps to define or reveal the form of an object. Light directly from the front tends to flatten a subject and will cause the subject to appear two-dimensional, while from the side it tends to sculpt and etch the subject away from its background. **Backlight** tends to push objects forward, while **downlight** tends to squash the subject. A light from below generally appears unnatural and can be used to create effects that clue audiences into peculiarities within a production. Architects can use these principles to make a room appear larger or smaller.

Quality refers to the texture and characteristic features of the light. Some lighting may be harsh and crisp—representing strong parallel rays—while other lighting will reflect a soft diffuse quality. Are the edges of the light and shadows sharp and well-defined or are they soft and fuzzy? Compare a clear sunny day in summer with the cold gray light associated with a December afternoon. Is the light even in distribution, or are there patterns? A typical contemporary classroom lighting scheme will most likely result in a soft, even wash of light over the entire room with some form of fluorescent fixtures. In comparison, a warehouse set in 1930 would probably be lit with single-bulb fixtures with simple shades that would produce cones of light throughout the structure. A walk on a sunny day through an open field exposes you to a very different kind of light than the textured light that you would expect once you move into a wooded area, where the trees create patches of light and shadow along your path. Lighting designers can create their own textured light by inserting patterns known as **gobos** into the fixtures that illuminate a space. While gobos were first utilized in entertainment designs, they have now become elements of architectural and display lighting as well.

Color

The third controllable quality of light is color, which is considered by many to be the most dynamic of the controllable qualities of light. Light will have an associated color that is determined through the specific collection of wavelengths present within its makeup. Hence, you might have a lavender light, a red light, or a blue light—each one distinguished from the others by those wavelengths of light found within its composition. However, color is actually a perception based on how specific wavelengths of the light stimulate the photo sensors in our eyes. Light, more importantly, has a major impact on

the color of any objects that it falls on, and the resultant color is a factor of both the object's surface color and that of the light that strikes the object. All objects selectively absorb or reflect various wavelengths of light—which becomes the means by which we determine the color of any object. The use of a light containing some or all of the wavelengths of light that are naturally reflected by an object will generally result in enhancing that object's color. On the other hand, the use of a colored light with limited or no common wavelengths with that of an object will result in a distortion and graying of that object's color. Color is produced through the spectral makeup of the light source itself, through the removal of specific wavelengths of the light through filtering, or by the selective absorption of a light's wavelengths by a surface. While it is generally agreed that color is the easiest quality of light to observe, it is also commonly acknowledged that due to the unpredictability of its results, it is perhaps the hardest quality to master and control.

Movement

The final quality of light is movement, which refers to changes in the light from moment to moment. This might be represented in a number of different ways: First, the actual movement of the light source. This is quite common and can be illustrated by a candle or flashlight carried across a room, where you actually see the source move from one location to another. A second form of movement involves observing the movement of the light without actually observing the light source directly. Two examples of this include watching the effect of a followspot on a rock musician and the use of a progression of lamps to light actors as they move from one stage position to another. In the first example, you see the effect of the light following the musician, but you can't see the actual spotlight because it is located somewhere behind you at the rear of the auditorium or arena. In the second example, lights slowly come up along the path that the actors walk such that the individual lights precede the arrival of the actors to specific locations on the stage. For even more effect, the individual lights could also slowly dim down once the actors move beyond their positions to other locations along the path. The last element of movement relates simply to changes within the lighting over time. This is the one that theatrical lighting designers deal with most often as they create **cues** for a production. For all practical purposes this would come about through making changes in any of the other three controllable qualities of light. Lights suddenly getting brighter or dimmer, shifting to another color, or slowly moving to a different angle all form examples of this kind of movement. The movement may be nearly instantaneous (i.e., flipping a light switch on or off) or could involve long transitions like sunset sequences that are so subtle that a viewer isn't aware of the lighting changes being made from one moment to another. Movement can also be thought of as a transition in lighting. While there are occasions where the lighting for an environment may be static, most of us consider transitions in lighting to be just as important as the images that a designer creates for a given project.

In summary, all lighting conditions reflect the manipulation of these four qualities. Whether you light a building, a museum display, an opera, or any other form of entertainment, each moment that a viewer observes can be associated with a given combination of intensity, color, and distribution in the lighting. Movement can most often be directly related to the transitions between different "**moments**" (also called "**looks**," "**states**," or "**cues**"). Each of these terms refers to names that a designer may use to refer to a static view of the lighting. Movement provides the fluid, dynamic quality required in a lighting design—a quality that many of us believe is just as important as the combination of fixtures, colors, and intensities that one sees at any given time. If mounted correctly, the lighting can greatly enhance a production or project. If done incorrectly, it can quickly become an interruption or distraction for the viewers.

Sidebar 1.1 DESIGNER PROFILE

A creative force in the New York theatre since the mid-1970s, Ken Billington is one of Broadway's most successful lighting designers. He remembers his first attraction to stage lighting from when he was in the fourth grade. From that point on, all Ken "wanted to do was lighting," but it wasn't until he was in junior high school that he realized that there were actual "lighting designers" in the world and that it was a proper design discipline. Finishing high school, he went directly to Manhattan to study at The Lester Polakov Studio and Forum of Stage Design, apprenticing with both Peggy Clark and Tharon Musser. In fact, he often claims that he went to "Musser U" and credits that legendary designer with his first big break.

Ken has designed a hundred Broadway shows, 70 off-Broadway shows, and operas for companies worldwide, as well as for concerts, theme park

Ken Billington

Credit: photo courtesy Ken Billington

shows, and architecture. He is often associated with lighting large musicals and spectaculars, with design credits that include the original *Sweeney Todd, White Christmas, Footloose*, and *Chicago* (the longest-running American musical in history). For 27 seasons, he designed the Christmas and Easter shows at the Radio City Music Hall and has lit a range of celebrated personalities, including Ann-Margret, Shirley MacLaine, Carol Channing, Liberace, and Hugh Jackman. Ken's designs have enhanced such extraordinary projects as *Fantasmic* at Disneyland, the lavish aquatic show at Seaworld Parks (Orlando, Florida; San Diego, California; and San Antonio, Texas), productions at Busch Gardens (Williamsburg, Virginia), and spectacular ice shows, including *Stars on Ice*. His television work includes many PBS theatre, concert specials, and several episodes of the NBC series *Smash*. His architectural designs have highlighted such New York landmarks as Feinstein's 54 Below and Tavern on the Green. Ken has been honored with most of the awards presented for lighting design in the theatre, including a Tony Award for *Chicago* and the Distinguished Lighting Designer Award from the United States Institute for Theatre Technology (USITT). In 2016, Ken became only the third lighting designer to be inducted into the Theatre Hall of Fame.

Ken considers himself primarily a "Broadway" designer, but his career embraces many creations beyond the New York stage. "I have done as many as five Broadway shows in a year," he says, "and only one the following year, but that year might include six shows that tryout and hope to come to New York. As a freelance designer, you have no idea where the jobs will come from each year." He expanded his career beyond the theatre, he declares,

> "by using "common sense" to apply what I know about stage lighting in other areas of lighting design. The basics of lighting—angle, color, intensity, and *concept*—remain the same in all venues. The manner of execution may differ, and you may need a different technical language as you move from collaboration with a stage electrician to working with a contractor, but the final product is the same: *designed* lighting."

Ken's experience has underscored his belief that lighting is a collaborative process, and the challenges, rewards, and personal friendships that come with being part of a creative team are what keep him excited about his art: "I can't paint or draw a picture, but I can paint with light. It is the same for any artist. *Why* do you do this? And, of course, it's always thrilling to sit in a theatre and see what you have created on paper come to life."

In order to remain current in his always-evolving craft, he reads the trade magazines, attends conventions, and makes himself available to sales people who come to his studio, talking directly to company reps about innovations in technology. He maintains, however, that the best way to remain up-to-date is simply going out and admiring what his colleagues are doing and observing the current trends for himself. He remains an enthusiastic theatregoer. When asked what he considers Rule Number One in lighting design, Ken is firm: "Concept! No matter what the project, big or small—if there is no concept, you will usually get yourself and the production into trouble." Ken also believes in hands-on training:

> "The best way to learn how to light is by *lighting*, no matter what the project. You might do a great job or just an okay job, but remember that even if you really screw up, the worst that will happen is that you'll get fired—they don't take you out back and shoot you. No matter what the project, learn from it—look at what worked and what did not work and file it away and remember it for the future."

Functions of Lighting

There are numerous functions associated with lighting. Light is used to reveal. Many of the functions of lighting relate specifically to the manner in which light is used to reveal an object(s) or setting. While most lighting designers agree in principle with many of the named lighting functions discussed in the following sections, sometimes designers may combine several of these functions into larger groups or associate a different term with a given function. In these cases, what is important is the performance of the function rather than the specific name used by a given individual. In reality, lighting designers combine and modify the controllable qualities of light to produce the varied functions that we find within any specific lighting. I will discuss the functions of lighting from a more traditional theatrical or entertainment background first and then go on to relate several other functions of lighting that are more specific to other practices. Again, it is important to be aware that many of the functions are characteristic of all types of lighting design.

Visibility

Most lighting designers would argue that the most important element of lighting is **visibility.** Many even refer to it as the primary function of lighting. After all, isn't this why we created artificial light in the first place? Visibility simply refers to the principle of using light to reveal or illuminate objects. In the early days of lighting, the job of the designer was nothing more than to create enough light so that the audience or occupants of a space could see. In many ways this philosophy of lighting was based on the premise that more was better and that the more footcandles or lumens of light placed on a stage or in a room, the better visibility that you had. Since the 1950s or '60s, theatrical designing moved towards a concept that we call **selective visibility,** which simply refers to revealing to an audience only what needs to be seen. Hence, a less-revealing image on stage might be more appropriate for the dramatic action than a fully illuminated stage. In selective visibility, areas of low intensity, shadows, silhouettes, and high contrast can become effective elements in a lighting designer's arsenal of tools. An image of Dracula appearing from the shadows is much more terrifying than seeing him come to his next victim in full light. Until recently, architectural lighting has been known for being largely dependent on the quantity rather than the quality of its lighting, and most recommended practices of the past carefully specified the minimum number of footcandles that were required for a given **task** or environment. Finally, while it may appear obvious that the level of illumination plays a dominant role in the visibility of an object, it is not the only control that has an effect on whether you see something or not. The angle of the light also determines how much or little of an object is revealed to you. The color of the light might help an object either blend in or pop out from its background and will also enhance or gray the object's color. These are just a few of the additional elements that can have an effect on visibility.

Mood

Another function of lighting relates to creating **mood.** Mood refers to the observer's emotional response to the lighting. Lighting can be foreboding or inviting, carefree and light, energetic versus passive, or tragic and oppressive. In all of these and many more moods, the light provides an atmosphere or ambiance for the environment that is being lit. Other than visibility, mood is probably the function of lighting that has the next most important impression or effect on a viewer. Studies have shown that light can have a profound effect on individuals and their moods. In entertainment lighting, we often produce extreme ranges of mood for a given theatrical production or special event. These moods may also be changed many times throughout a two- or three-hour performance. Mood changes may occur quickly or may be so subtle that the audience isn't necessarily aware that the changes have even taken place. A well-lit production will have lighting that reflects the varied moods of a piece while also following the rhythm of the changes that occur throughout the script. In architectural lighting, more subtle choices are used to produce environments for more productive offices, more welcoming reception areas, and to provide calming effects for patients in medical facilities. Lighting has also been used to influence sales volumes and turnover rates in retail markets. As an example, consider the lighting associated with a fine restaurant like a favorite bistro versus any number of fast-food restaurants. The soft, amber lighting associated with a bistro is very different from the harsh, bright, fluorescent lighting that is characteristic of most fast-food restaurants, where turnover is key to a successful business. In this case, the lighting helps create an environment that prevents patrons from becoming too comfortable in fast-food establishments.

Establishing a Scene

Some functions of lighting are related specifically to the discipline that you are designing within, while others are consistent with almost any kind of lighting. For instance, in a theatrical production it would be critical for the lighting to help establish or communicate specific information about the play or environment that is being created. Time of day, season, and geographical location are all parts of this function. Many refer to this