

illuminating Engineering Society

THE LIGHTING HANDBOOK

Tenth Edition | Reference and Application



David L. DiLaura
Kevin W. Houser
Richard G. Mistrick
Gary R. Steffy

Currently in preview, click buy full version

Illuminating Engineering Society

The Lighting Handbook

Tenth Edition: Reference and Application

Currently in preview, click buy full version

Currently in preview, click buy full version

Illuminating Engineering Society

The Lighting Handbook

Tenth Edition: Reference and Application

David L. DiLaura
Kevin W. Houser
Richard G. Mistrick
Gary R. Steffy



The product development process brings together volunteers representing varied viewpoints and interests to achieve consensus on lighting recommendations. While the IES administers the process and establishes policies and procedures to promote fairness in the development of consensus, it makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

The IES disclaims liability for any injury to persons or property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document.

In issuing and making this document available, the IES is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the IES undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The IES has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the IES list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or statement of compliance with the requirements of this document shall not be attributable to the IES and is solely the responsibility of the certifier or maker of the statement.

It is acknowledged by the editors and publisher that all service marks, trademarks, and copyrighted images/graphics appear in this book for editorial purposes only and to the benefit of the service mark, trademark, or copyright owner, with no intention of infringing on that service mark, trademark, or copyright. Nothing in this handbook should be construed to imply that respective service mark, trademark, or copyright holder endorses or sponsors this handbook or any of its contents.

This book was set in Adobe® Garamond Pro by the editors. This book is printed in environment friendly ink containing soy and vegetable oil on paper that is acid free and elemental chlorine free and contains 10% post consumer waste recycled content exhibiting an 86% reflectance.

For general information about other IES publications, please visit the IES Bookstore at www.ies.org/store.

Illuminating Engineering Society, The Lighting Handbook, Tenth Edition

Copyright ©2011 by the Illuminating Engineering Society of North America.

All rights reserved. No part of this publication may be reproduced in any form, in any electronic retrieval system or otherwise, without prior written permission of the IES.

Published by the Illuminating Engineering Society of North America, 120 Wall Street, New York, New York 10005.

IES Standards and Codes are developed through committee consensus and produced by the IES Office in New York. Careful attention is given to style and accuracy. If any errors are noted in this document, please forward them to Director of Technology, at the above address for verification and correction. The IES welcomes and urges feedback and comments.

ISBN 978-087995-241-9

Library of Congress Control Number: 2011928648

Printed in the United States of America.

FOREWORD

In the early years, the Illuminating Engineering Society, founded in 1906, waited 41 years before issuing the first edition of the Handbook. Technical information was not lacking but the preferred method of publication were Transactions of the Society, not as widely disseminated or conveniently available to as broad an interested audience as a Handbook. Between the 1st edition in 1947 and this 10th Edition there have been revisions in 1952, 1959, 1966, 1972, 1981, 1984 (partial), 1987 (partial), 1993, and 2000.

In each book an ever-broadening range of technologies, procedures, and design issues has been addressed to ensure that the Handbook is the principal source for lighting knowledge. The emphasis in each edition has changed to reflect current application trends and needs of the many and varied readership. Some editions placed more importance on quantitative issues; in more recent years, quality earned important recognition.

The Tenth Edition Handbook has taken cognizance of several issues that impact designs of today: energy limits, the spectral effects of light on perception and visual performance, and the need for flexibility in an illumination determination procedure that takes into account factors such as observer age, task reflectance, and task importance in its illumination determination procedure. This book will return to a more “analytical” approach to recommendations and allow the individual committees’ publications, such as Recommended Practices, Design Guides, and Technical Memoranda to fully address appropriate and specific design details for a given application.

The professional editorial team brought talent and discipline to the project. This was not a simple revision to an existing book but an entirely new approach. David DiLaura, Kevin Houser, Richard Mistrick, and Gary Steffy have earned our appreciation for their contributions in developing new material, editing, and designing the overall appearance of the book.

The Lighting Handbook represents the most important reference document in the lighting profession. It is one by which the Society accomplishes its mission: To improve the lighted environment by bringing together those with lighting knowledge and by translating that knowledge into actions that benefit the public. We hope that you, the reader, will find the Tenth Edition your principal reference source for lighting information.

William H. Hanley
Executive Vice President

Rita M. Harrold
Director of Technology

Currently in preview, click buy full version

PREFACE

The Illuminating Engineering Society produces The Lighting Handbook to guide and give authoritative recommendations to those who design, specify, install, and maintain lighting systems, and as an impartial source of information for the public. Like previous editions, the Lighting Handbook contains a mix of science, technology, and design; mirroring the nature of lighting itself.

Three sections make up this edition: *Framework*, *Design*, and *Applications*. *Framework* chapters describe the science and technology related to lighting, including vision, optics, non-visual effects of optical radiation, photometry, and light sources. *Design* chapters include not only fundamental considerations and special issues of daylighting and electric lighting design, but also energy management, controls, and economics. *Applications* chapters establish the design context for many lighting applications, provide illuminance recommendations for specific tasks and areas, and identify some of the analytic goals of lighting design using science and technology.

In the decade since the last edition, the science, technology, and design practice related to lighting have advanced significantly. Vision and biological sciences have deepened knowledge of the complex relationship between light and health, adding both opportunity and responsibility to the work of those who design lighting systems, and heightened the awareness of the public of how lighting affects our lives. Technology has transformed lighting with the light emitting diode, now a practical source for general illumination. New equipment, new testing procedures, and new application considerations have all arisen in response to this development. And the philosophy, goals, and practice of architectural design have been deeply affected by concerns for the natural environment and desires for more sustainable buildings. New developments in daylighting, sustainable practices, and lighting control technology provide ways to respond to these concerns and expectations. This edition of The Lighting Handbook describes all of these important advances and changes, providing overviews, descriptions, data and guidance.

New and extensive coverage of lighting design is provided in the *Design* chapters. Daylighting and lighting controls are treated in particular detail. This reveals daylighting's potential and subsequent effects on building design, so that daylighting and electric lighting may act in concert to produce better luminous environments. The consequences of this for building energy can be very large if controls are an integral part of lighting systems, and the chapter on lighting controls shows how this can be done. Related to this and to augment the technical information provided in a *Framework* chapter, the *Design* section of The Lighting Handbook includes a chapter on the application issues involved in electric light sources.

The public hope and expectation of diminishing the energy allotted to buildings have increased the challenge of providing the lighting required for comfort, performance, safety, and the appropriate lighting of architecture. In response to these constraints, the IES has established a new illuminance determination system to generate new recommended illuminance targets cited in the *Applications* chapters of this edition of The Lighting Handbook. The new system uses a series of closely spaced increments of illuminance that are assigned to tasks. This finer granularity, in comparison to that used in earlier editions, gives the designer and client the ability to more carefully match illuminance targets with visual tasks. Additionally, most recommendations now account for the age of the occupants: lower values for young occupants, higher values for older occupants. The effects of

mesopic adaptation on the spectral sensitivity of the visual system are now accommodated with multipliers based on adaptation luminance that can be used to adjust recommended illuminance targets. Finally, recommended illuminance targets for outdoor applications now account for activity level and environmental conditions. All of these features of the new illuminance determination system give extensive flexibility that enable the designer to address lighting needs and promote the control of light in time. The recommended illuminance targets given in each of the application chapters are based on this new system.

One of the many significant changes in *The Lighting Handbook* has been in the intent and form of the application chapters: they no longer contain a full description of lighting practice. Rather, they give only a brief context for the principal aspects of the application and a detailed table of analytic recommendations for the tasks involved. The complete description of all aspects of a particular application is now contained only in the Society's respective Recommended Practice, Design Guide, or Technical Memorandum publication. This separation of intended coverage permits handbook chapters to make stable analytic recommendations, while allowing more flexibility for timely revisions to the more practice-based Recommended Practices, Design Guides, and Technical Memoranda.

Among the many effects of the new technology and understanding of light and well-being, has been the emergence of wide interest in new lighting technologies and large questions of public policy regarding lighting, energy, sustainability, and health. For these reasons this edition of *The Lighting Handbook* has been designed and written for a very wide audience, changing the form, content, and style from past editions. Unlike those, this has been written, literally, by its four editors, permitting a certain uniformity of approach, scope, level of detail, and target audience. This has also helped reduce redundancy and assure the accessibility required to reach a wide audience. Every effort for concision has been made, and wherever possible, important data, material, check lists, or key factors have been summarized in tables. Though written by a small group, the recommendations and content of each chapter has been widely reviewed by experts in each topic, the appropriate application committee, and the Society's Technical Review Council and Board of Directors.

This edition of *The Lighting Handbook* provides information and recommendations that can guide designers and users of lighting systems in a world of both reduced lighting energy expectations and undiminished needs for attractive, comfortable, productive luminous environments.

David L. DiLaura

Kevin W. Houser

Richard G. Mistrick

Gary R. Steffy

Table of Contents
Framework

PHYSICS AND OPTICS OF RADIANT POWER	1
VISION: EYE AND BRAIN	2
PHOTOBIOLOGY AND NONVISUAL EFFECTS OF OPTICAL RADIATION	3
PERCEPTIONS AND PERFORMANCE	4
CONCEPTS AND LANGUAGE OF LIGHTING	5
COLOR	6
LIGHT SOURCES: TECHNICAL CHARACTERISTICS	7
LUMINAIRES: FORMS AND OPTICS	8
MEASUREMENT OF LIGHT: PHOTOMETRY	9
CALCULATION OF LIGHT AND ITS EFFECTS	10

Table of Contents
Design

LIGHTING DESIGN: IN THE BUILDING DESIGN PROCESS	11
COMPONENTS OF LIGHTING DESIGN	12
LIGHT SOURCES: APPLICATION CONSIDERATIONS	13
DESIGNING DAYLIGHTING	14
DESIGNING ELECTRIC LIGHTING	15
LIGHTING CONTROLS	16
ENERGY MANAGEMENT	17
ECONOMICS	18
SUSTAINABILITY	19
CONTRACT DOCUMENTS	20

Table of Contents
Applications

LIGHTING FOR ART	21
LIGHTING FOR COMMON APPLICATIONS	22
LIGHTING FOR COURTS AND CORRECTIONAL FACILITIES	23
LIGHTING FOR EDUCATION	24
LIGHTING FOR EMERGENCY, SAFETY, AND SECURITY	25
LIGHTING FOR EXTERIORS	26
LIGHTING FOR HEALTH CARE	27
LIGHTING FOR HOSPITALITY AND ENTERTAINMENT	28
LIGHTING FOR LIBRARIES	29
LIGHTING FOR MANUFACTURING	30
LIGHTING FOR MISCELLANEOUS APPLICATIONS	31
LIGHTING FOR OFFICES	32
LIGHTING FOR RESIDENCES	33
LIGHTING FOR RETAIL	34
LIGHTING FOR SPORTS AND RECREATION	35
LIGHTING FOR TRANSPORT	36
LIGHTING FOR WORSHIP	37

Framework

Framework

PHYSICS AND OPTICS OF RADIANT POWER	1
VISION: EYE AND BRAIN	2
PHOTOBIOLOGY AND NONVISUAL EFFECTS OF OPTICAL RADIATION	3
PERCEPTIONS AND PERFORMANCE	4
CONCEPTS AND LANGUAGE OF LIGHTING	5
COLOR	6
LIGHT SOURCES: TECHNICAL CHARACTERISTICS	7
LUMINAIRES: FORMS AND OPTICS	8
MEASUREMENT OF LIGHT: PHOTOMETRY	9
CALCULATION OF LIGHT AND ITS EFFECTS	10