



Designers Lighting Forum

Designing with Luminance and Exitance

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.



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Learning Objectives

At the end of the this course, participants will be able to:

1. Identify luminance design criteria
2. Recognize tools for evaluating luminance design criteria
3. Compare illuminance and exitance as measures of perceived adequacy of illumination
4. Recognize tools for the analysis of mean room surface exitance



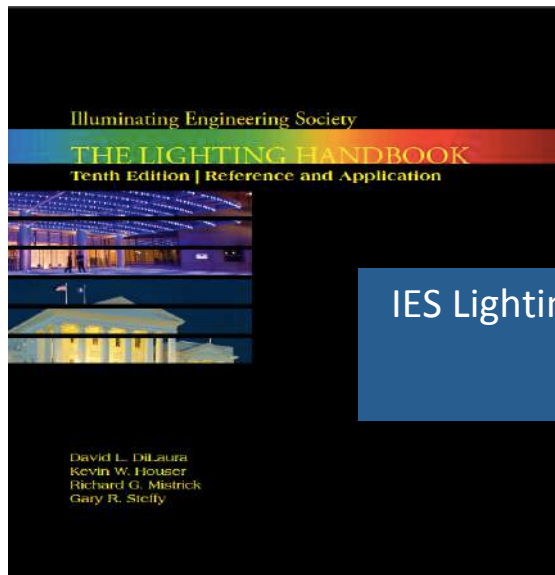
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Designing with Luminance and Exitance

1. Lighting Design Approaches
2. Designing with Luminance
3. Designing with Exitance
4. Measuring Luminance and Exitance in the Field

Lighting Design Approaches

- Design for Visual Performance
 - Design lighting to perform a task, e.g., reading, writing, safe egress, etc.
 - “Heads down” approach
 - Often thought of in terms of delivering the right *quantity* of light



IES Lighting Handbook, 2011 10th Edition

Table 4.1 | Recommended Illuminance Targets

Category	Recommended Illuminance Targets (lux)			Some Typical Application and Task Characteristics	Visual Performance Description	
	Visual Ages of Observers (years) where at least half are					
	<25	25 to 65	>65			
Interior and exterior applications	A	0.5	1	2	• Dark adapted situations • Basic convenience situations • Very low-activity situations	Orientation, relatively large-scale, physical (less cognitive) tasks Visual performance is typically not work-related, but related to dark sedentary social situations, senses of safety and security, and casual circulation based on landscape, hardscape, architecture, and people as visual tasks.
	B	1	2	4		
	C	2	4	8	• Slow-paced situations • Low-density situations	
	D	3	6	12	• Slow-to-moderate-paced situations • Moderate-to-high-density situations	
	E	4	8	16		
	F	5	10	20	• Moderate-to-fast-paced situations • High-density situations	
	G	7.5	15	30	• Some indoor very subdued circulation situations • Some indoor social situations	
	H	10	20	40		
Interior and exterior	I	15	30	60	• Congested and significant outdoor intersections, important decision points, gathering places, and key points of interest • Some indoor social situations • Some indoor commerce situations	
	J	20	40	80		Common social activity and large and/or high-contrast tasks Visual performance involves higher-level assessment of landscape, hardscape, architecture, and people and can be work-related.
Interior and exterior applications	K	25	50	100		Common, relatively small-scale, more cognitive or task-performance visual tasks Visual performance is typically daily life- and work-related, including much reading and writing of handcopies and electronic media consecutively and/or simultaneously.
	L	27.5	75	150	• Some outdoor commerce situations • Some indoor social situations • Some indoor commerce situations	
	M	50	100	200		
	N	75	150	300		
	O	100	200	400	• Some indoor social situations • Some indoor education situations • Some indoor commerce situations • Some indoor sports situations	
	P	150	300	600		
	Q	200	400	800	• Some indoor education situations • Some indoor commerce situations • Some indoor sports situations • Some indoor industrial situations	
	R	250	500	1000		
	S	375	750	1500		
	T	500	1000	2000	• Some sports situations • Some indoor commerce situations • Some indoor sports situations	
Interior and exterior applications	U	750	1500	3000		Small-scale, cognitive visual tasks Visual performance is work- or sports-related, close and distant fine-inspection, very small detail, high-speed assessment and reaction.
	V	1000	2000	4000		Unusual, extremely minute and/or life-sustaining cognitive tasks Visual performance is of the highest order in respective fields of health care, industrial, and sports.
	W	1500	3000	6000	• Some sports situations • Some indoor industrial situations • Some health care procedural situations	
	X	2500	5000	10000		
Y	5000	10000	20000	• Some health care procedural situations		

10th Edition Illuminance Categories

Category	Recommended Target Illuminances (lux)			Some Typical Application and Task Characteristics	Visual Performance Description	
	Visual Ages of Observers (years) where at least half are					
	<25	25 to 65	>65			
Interior and exterior applications	A	0.5	1	2	• Dark adapted situations • Basic convenience situations • Very low-activity situations	Orientation, relatively large-scale, physical (less-cognitive) tasks Visual performance is typically not work-related, but related to dark sedentary social situations, senses of safety and security, and casual circulation based on landscape, hardscape, architecture, and people as visual tasks.
	B	1	2	4		
	C	2	4	8	• Slow-paced situations • Low-density situations	
	D	3	6	12	• Slow-to-moderate-paced situations • Moderate-to-high-density situations	
	E	4	8	16		
	F	5	10	20	• Moderate-to-fast-paced situations • High-density situations	
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Recommended Target Illuminances (lux)						
Visual Ages of Observers (years) where at least half are:						
Category	<25	25 to 65	>65	Some Typical Application and Task Characteristics	Visual Performance Description	
Interior and exterior applications	J	20	40	80	<ul style="list-style-type: none"> • Some outdoor commerce situations • Some indoor social situations • Some indoor commerce situations 	<p>Common social activity and large and/or high-contrast tasks</p> <p>Visual performance involves higher-level assessment of landscape, hardscape, architecture, and people and can be work related.</p>
	K	25	50	100		
	L	37.5	75	150		
	M	50	100	200		
	N	75	150	300		
	O	100	200	400		
P	150	300	600	<ul style="list-style-type: none"> • Some indoor social situations • Some indoor education situations • Some indoor commerce situations • Some indoor sports situations 	<p>Common, relatively small-scale, more cognitive or fast-performance visual tasks</p>	

Recommended Target Illuminances (lux)						
Visual Ages of Observers (years) where at least half are:						
Category	<25	25 to 65	>65	Some Typical Application and Task Characteristics	Visual Performance Description	
Interior and exterior applications	Q	200	400	800	<ul style="list-style-type: none"> • Some indoor education situations • Some indoor commerce situations • Some indoor sports situations • Some indoor industrial situations 	<p>Visual performance is typically daily life- and work-related, including much reading and writing of hardcopies and electronic media consecutively and/or simultaneously.</p>
	R	250	500	1000		
	S	375	750	1500		
	T	500	1000	2000	<ul style="list-style-type: none"> • Some sports situations • Some indoor commerce situations • Some indoor industrial situations 	<p>Small-scale, cognitive visual tasks</p> <p>Visual performance is work- or sports-related, close and distant fine inspection, very small detail, high-speed assessment and reaction.</p>
	U	750	1500	3000		
	V	1000	2000	4000		
	W	1500	3000	6000		
Interior applications	X	2500	5000	10000	<ul style="list-style-type: none"> • Some healthcare procedural situations 	<p>Unusual, extremely minute and/or life-sustaining cognitive tasks</p> <p>Visual performance is of the highest order in respective fields of healthcare, industrial, and sports.</p>
	Y	5000	10000	20000		

Table 24.2 | Educational Facilities Illuminance Recommendations

Applications and Tasks*	Notes	Recommended Maintained Illuminance Targets (lux) ^{b,c,d}									Uniformity Targets ^e Over Area of Coverage (E_{min}/E_{max}) ^f or (E_{min}/E_{avg}) ^g or Min/Avg	Typical Area of Coverage ^h Task Area Room or Designated Area	Notes for Table 24.2
		Horizontal (E _h) Targets			Vertical (E _v) Targets								
		Visual Ages of Observers (years) where at least half are			Visual Ages of Observers (years) where at least half are								
		<25	25-65	>65	<25	25-65	>65						
ACCENTING	Accenting influences observers' overall brightness perceptions and provides visual relief. Accenting is also used for visual attraction and wayfinding. See 22 LIGHTING FOR COMMON APPLICATIONS/ACCENTING for default accenting criteria for consideration in any application.												
ADMINISTRATION	See 22 LIGHTING FOR COMMON APPLICATIONS												
AUDITORIUM	As the architect coordinates contrast markings with steps, curbs, and ramps, localized lighting may be deemed appropriate.												
• Circulation	As the architect coordinates contrast markings with steps, curbs, and ramps, localized lighting may be deemed appropriate.												
• AV or performance													
• All-but-AV-or-performance													
• Control Booths	See 28 LIGHTING FOR HOSPITALITY AND ENTERTAINMENT												
• Lecture Hall	Dedicated to lectures (likely fixed seating)												
• Audience	As the architect coordinates contrast markings with steps, curbs, and ramps, localized lighting may be deemed appropriate.												
• AV and notes	Notetaking is intended. E _v @2' AFF; E _v @4' AFF	K	25	30	100	Avg	G	7.5	15	30	Avg		
• AV and no notes	No notetaking is intended. E _v @floor; E _v @4' AFF	F	5	10	20	Avg	D	3	6	12	Avg		
• Feature presentation	E _v @floor; E _v @4' AFF	F	5	10	20	Avg	D	3	6	12	Avg		
• No AV	E _v @2' AFF; E _v @4' AFF	M	50	100	200	Avg	J	20	40	80	Avg		
• Demonstration	E _v @2' AFF; E _v @4' AFF	T	300	1000	2000	Avg	R	250	500	1000	Avg		
• Screen (front projection)	Cited values are intended for screen plane when screen is in use												
• Feature presentation													
• Periodic reference													
• Speaker (Panel)	Lighting at the speaker or panel of speakers												
• AV													
• Face(s)	E _v @4' AFF												
• Task surface	E _v @2' AFF; E _v @4' AFF												
• No AV	E _v @2' AFF; E _v @4' AFF	R	250	500	1000	Avg	O	100	200	400	Avg		
• Multipurpose	High degree of flexibility (likely loose seating)												
• Assembly	As the architect coordinates contrast markings with steps, curbs, and ramps, localized lighting may be deemed appropriate.												
• Audience													
• AV and notes	Notetaking is intended. E _v @2' AFF; E _v @4' AFF	K	25	30	100	Avg	G	7.5	15	30	Avg		

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		Horizontal (E _h) Targets			Vertical (E _v) Targets								
		Visual Ages of Observers (years) where at least half are			Visual Ages of Observers (years) where at least half are								
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• No AV	E _v @2' AFF; E _v @4' AFF	M	50	100	200	Avg	J	20	40	80	Avg		
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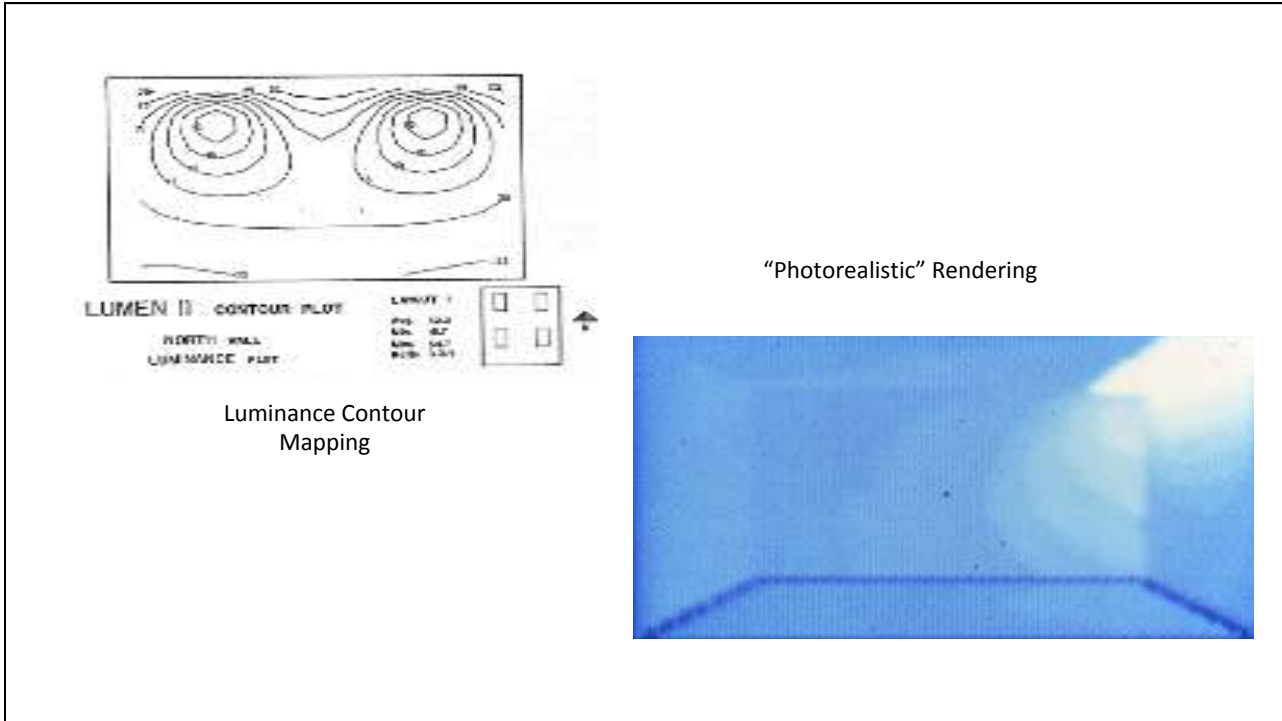
Lighting Design Approaches

- Design for the Visual Environment
 - Design lighting for entire environment, taking into account lighting of surfaces and interaction of lighting elements
 - “Heads up” approach
 - Often thought of in terms of delivering the right *quality* of light



Luminance-Based Design

- J.M. Waldram (1954). Designed Appearance Method: “There has been a revolution in thought in interior lighting in the past eight years – beyond illuminating the task plane, includes ‘decoration, brightness distributions, comfort, emphasis modeling . . .’”
- R.G. Hopkinson (1965). A Proposed Luminance Basis for a Lighting Code.
- A. M. Marsden (1970). Brightness Luminance Relationships in an Interior.
- C.A. Bernecker (1980). The potential for design applications of luminance data. JIES: “The concept of a total visual environment implies design that accounts for the light distribution and intensity on all surfaces within an architectural space.”




Luminance Contour Mapping

“Photorealistic” Rendering

IESNA Design Guides

IESNA Lighting Design Guide Interior-1

I. INTERIOR LOCATIONS AND TASKS	Legend: <input checked="" type="checkbox"/> Very Important <input type="checkbox"/> Important <input type="checkbox"/> Somewhat important <input type="checkbox"/> Blank = Not important or not applicable																								
	Design Issues	Appearance of Space and Luminaires	Color Appearance (incl Color Contrast)	Daylighting Integration and Control	Direct Glare	Flicker (and Strobe)	Light Distribution on Surfaces	Light Distribution on Task Plane (Uniformity)	Luminances of Room Surfaces	Modeling of Faces or Objects	Point(s) of Interest	Reflected Glare	Shadows	Source/Task/Eye Geometry	Sparkle/Desirable Reflected Highlights	Surface Characteristics	System Control and Flexibility	Special Considerations	Notes on Special Considerations	Illuminance (Horizontal)	Category or Value (lux)	Illuminance (Vertical)	Category or Value (lux)	Notes on Illuminance - see end of section	Reference Chapter(s)
Accounting (see Offices)																									Ch. 11
Air Terminals (see Transportation Terminals in Section V, Transportation)																									Ch. 23
Armories																					C		A		Ch. 14
Art Galleries (see Museums)																									Ch. 14
Auditoriums																									
Assembly																					B		A		
Social activity																									
Banks (see Reading)																									Ch. 11
Lobby																									
General																					(1)		A		
Writing area																					(2)		A		
Tellers' stations																					(3)		A		
ATM facilities — keypad																					(4)		C		



22 | LIGHTING FOR COMMON APPLICATIONS

New options are always explored, and usually applied, unless an other reason has been given as an already reason.
John Loebe, 17th Century, Philosopher and Poetist

There need not be anything commonplace about lighting for applications that are common to many building projects. Some of these applications, such as lobbies, make first impressions. Others, like conferencing and food service can be the amenities that set one workplace apart from others. Lighting for these applications is important and can define a facility with uncommon character. Daylighting is quite effective in addressing illuminance in many of these applications.

Comprehensive design efforts involve the information in this chapter combined with material in 12 | COMPONENTS OF LIGHTING DESIGN, 13 | LIGHT SOURCES, APPLICATION CONSIDERATIONS, 14 | DESIGNING DAYLIGHTING, and 15 | DESIGNING ELECTRIC LIGHTING. Design teams should appropriate from these chapters as needed and lighting goals and strategies developed accordingly. This chapter primarily addresses illuminance criteria for common applications which should reference luminance, spatial, acoustic, acoustic, and final layout based on design through systems (see 15.2.4 Lighting Systems). Use of the material in this chapter in the evolution of material in Chapters 12, 13, 14, and 15 will likely lead to satisfactory results. Practice RE related illuminance rates as outlined reference systems [1].

Diffusion through most in green to reach beyond the recommended illuminance in this chapter. For example, in FOOD SERVICE/Bar/Back line, the vertical illuminance criterion does not necessarily demand a uniform array of low-mounting workstations. Each lighting can be achieved with night or downlight or downlight in such that a preference also like downlight along the back bar elevation, adjustable armature, the number of daylighting in the top of the back bar (for at least the daytime condition) or some combination of these. Each of these can achieve the target illuminance. This can be a distinctly different approach and requires different architectural detailing. Such specific details are not contained in this table. Table 22.1 offers a checklist of RE lighting topics and criteria. The design team is responsible for determining and addressing indoor and outdoor lighting and energy related as well as ambient lighting parameters (AM) which may be different from and separate IES criteria. See also 23 | LIGHTING FOR EMERGENCY, SAFETY, AND SECURITY.

22.1 Project Type and Status

Before any design work, an understanding of the project type and scope is necessary. This will establish the extent to which daylighting can address most or many or some of the lighting goals. How, orientation, and orientation process each offer varying opportunities. See 11.7 Planning, 11.8.3 Psychology, and 11.8.3 Schematic Design. An early opportunity the lighting designer should give every consideration to daylighting as a light source. For some applications and tasks, daylighting can be the primary light source. Generally, the main addressing the best of lighting design factors identified in 12 | COMPONENTS OF LIGHTING DESIGN. Daylight demands attention to moderate or climate plans and balance visible and thermal energy.

ES 106 | Table

Applications | Lighting for Common Applications

Table 22.1 | Common Applications Lighting Checklist

Accenting

- 15.1.1.3 Accent Lighting
- Table 12.2 | Subjective Impressions
- Table 15.2 | Accent Illuminance Ratios
- Table 22.1 | Common Applications Illuminance Recommendations

Appearance

- 12.2 Spatial Factors

Color

- 4.10.1 Discomfort Glare
- 4.10.3 Disability Glare

Controls

- 16 | LIGHTING CONTROLS

Daylighting

- 14 | DESIGNING DAYLIGHTING

Electric Lighting

- 15 | DESIGNING ELECTRIC LIGHTING

Flicker

- 4.6 Flicker and Temporal Contrast Sensitivity

Glare

- 4.10.1 Discomfort Glare
- 4.10.3 Disability Glare

Illuminance

- This Chapter: Table 22.2

Table 22.2 | Common Applications Illuminance Recommendations

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Chapter Table 22.2

- 12.5.1 Applications and Tasks
- Table 12.6 | Default Illuminance Ratio Recommendations
- Figure 12.22 | Task Coverage Example

Light Distribution

- 12.3.2 Subjective Impressions

Luminance

- Table 12.5 | Default Luminance Ratio Recommendations

Maintenance

- 15.4.4 Installation and Maintenance

Nighttime Outdoor Environment

- Table 15.6 | Nighttime Operational Strategies for Improved Outdoor Environmental Regard

Systems Integration

- 12.6 Systems Factors

Veiling Reflections

- This Chapter: Section 22.3.6
- 12.5.4 Veiling Reflections

Visual Tasks

- This Chapter: Section 22.2
- This Chapter: Table 22.2
- Table 11.2 | Programming: Inventory Scope and Specific Examples
- 12.5.1 Visual Tasks
- Table 12.3 | Sample Visual Task Survey

Table 22.1 | Common Applications Lighting Checklist

Topics

✓ **Criteria and Design Resources**

Accenting

- 15.1.1.3 Accent Lighting
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Illuminance

Table 12.6 | Default Illuminance Ratio Recommendations
 Figure 12.22 | Task Coverage Example

Light Distribution

12.3.2 Subjective Impressions

Luminances

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 Table 12.5 | Default Luminance Ratio Recommendations

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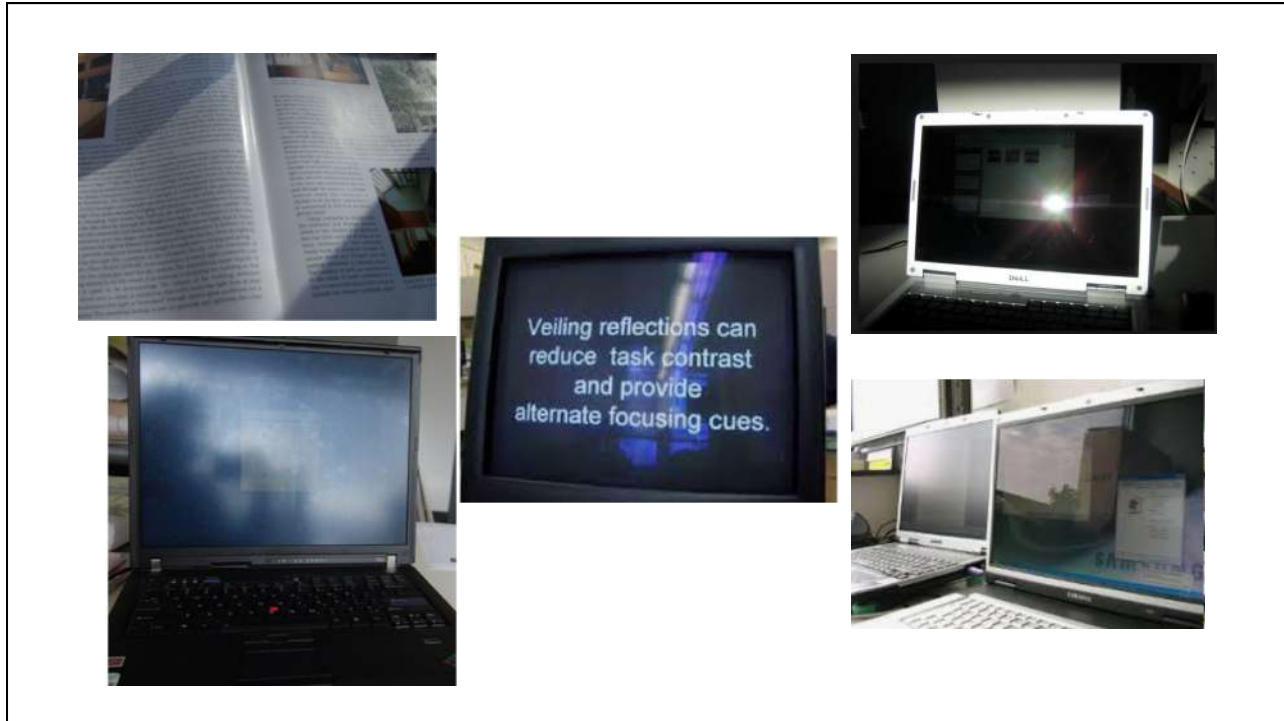


Table 12.4 | Default Luminance and Luminaire Intensity Recommendations for VDT Applications

Luminance Source	VDT Viewing Significance ^a	Application ^b	Average Initial Luminaire Luminance Option ^c				Maximum Initial Luminaire Candlepower Option ^d	
			VDT Monitor Screen Reflection Properties					
			Medium-to-good ^a CSA/ISO Types I and II Monitors		Poor ^a CSA/ISO Type III Monitors			
		Positive Polarity	Negative Polarity	Positive Polarity	Negative Polarity	Luminaire Candlepower Limits		
Luminaires (direct component)	Secondary	- Industrial	≤2570 cd/m ² at 65° and above				NA	
		- Conference Room	≤1715 cd/m ² at 65° and above				300 cd @65°, 185 cd @75°, 60 cd @85°	
		- Transitional Space	≤1715 cd/m ² at 65° and above				300 cd @65°, 185 cd @75°, 60 cd @85°	
	Normal	- Classroom	≤1500 cd/m ² at 65° and above	≤1000 cd/m ² at 65° and above	≤500 cd/m ² at 65° and above	≤200 cd/m ² at 65° and above	300 cd @65°, 185 cd @75°, 60 cd @85°	
		- High-tech Industrial	≤1500 cd/m ² at 65° and above	≤1000 cd/m ² at 65° and above	≤500 cd/m ² at 65° and above	≤200 cd/m ² at 65° and above	300 cd @65°, 185 cd @75°, 60 cd @85°	
		- Office	≤1500 cd/m ² at 65° and above	≤1000 cd/m ² at 65° and above	≤500 cd/m ² at 65° and above	≤200 cd/m ² at 65° and above	300 cd @65°, 185 cd @75°, 60 cd @85°	
	High	- Call Centers	≤1500 cd/m ² at 55° and above	≤1000 cd/m ² at 55° and above	≤500 cd/m ² at 55° and above	≤200 cd/m ² at 55° and above	300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°	
		- Programming ^f	≤1500 cd/m ² at 55° and above	≤1000 cd/m ² at 55° and above	≤500 cd/m ² at 55° and above	≤200 cd/m ² at 55° and above	300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°	
	Critical	- Air Traffic Control	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°	
		- CAD	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°	
- Programming ^g		≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°		
- Command Centers		≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°		
- Medical Lab		≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°		
- Monitoring	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°			
Daylight Media	Secondary	- Conference Room	≤3425 cd/m ²					
		- Transitional Space	≤3425 cd/m ²					
		- Industrial	≤2570 cd/m ²					
	Normal	≤855 cd/m ²						
	Critical	≤615 cd/m ²						

Photometry – 4000K CCT		Candela distribution			Coefficients of utilization										Zonal lumen summary*																												
Report number ¹ :	G2012327	Vertical Angle	Horizontal Angle		Zonal Lumens	Ceiling	80%			50%			30%			Zone	Lumens	% Lamp	% Fixt.																								
Catalog number:	CFS22GPG28L40ULAG	0	1020	1020	1020	Wall	70	50	30	50	30	10	50	30	10	0- 30	784	27.8	27.8																								
Delivered lumens:	2820	5	1012	1014	1018	RC	Zonal Cavity Method										0- 40	1280	45.4	45.4																							
Color ² :	4000K	15	958	972	987	RW	Effective Floor Reflectance = 20%										0- 60	2256	80.0	80.0																							
Input watts:	46.8	25	865	895	929	1	109	104	100	98	95	92	94	91	89	0- 90	2820	100.0	100.0																								
Efficacy:	60.3 lm/w	35	740	791	846	2	99	91	84	86	80	76	82	78	74	90-180	0	0	0																								
CRI:	83.8	45	594	666	738	3	90	80	72	75	69	64	73	67	62	0-180	2820	100.0	100.0																								
Lamp:	LED	55	428	522	602	4	83	71	62	67	60	54	65	58	53	*Total Efficiency																											
Luminaire:	Coffaire recessed LED 2' x 2' fixture with perforated basket.	65	258	361	413	5	76	63	54	60	53	47	58	51	46																												
CIE Type:	Direct	75	128	172	201	6	70	57	48	54	47	41	52	46	41																												
Plane:	0-Deg. 90-Deg.	85	28	35	36	40	7	65	52	43	49	42	36	48	41																												
Spacing criteria:	1.2 1.3	90	3	3	3		8	61	47	39	45	38	32	44	37																												
Plane:	0-Deg. 90-Deg.	1 Tested using absolute photometry as specified in LM79-IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products. 2 Correlated Color Temperature within specs as defined in ANSI_NEMA_ANSI C78 377-2008: Specifications for the Chromaticity of Solid State Lighting Products.																																									
Luminous length:	23.040 23.040	Avg. Luminance (cd/m²) <table border="1"> <thead> <tr> <th>Vertical Angle</th> <th colspan="3">Horizontal Angle</th> </tr> <tr> <th></th> <th>0°</th> <th>45°</th> <th>90°</th> </tr> </thead> <tbody> <tr> <td>45</td> <td>2452</td> <td>2749</td> <td>3046</td> </tr> <tr> <td>55</td> <td>2178</td> <td>2656</td> <td>3063</td> </tr> <tr> <td>65</td> <td>1782</td> <td>2493</td> <td>2852</td> </tr> <tr> <td>75</td> <td>1444</td> <td>1940</td> <td>2267</td> </tr> <tr> <td>85</td> <td>938</td> <td>1172</td> <td>1206</td> </tr> </tbody> </table>														Vertical Angle	Horizontal Angle				0°	45°	90°	45	2452	2749	3046	55	2178	2656	3063	65	1782	2493	2852	75	1444	1940	2267	85	938	1172	1206
Vertical Angle	Horizontal Angle																																										
	0°	45°	90°																																								
45	2452	2749	3046																																								
55	2178	2656	3063																																								
65	1782	2493	2852																																								
75	1444	1940	2267																																								
85	938	1172	1206																																								

Table 12.4 | Default Luminance and Luminaire Intensity Recommendations for VDT Applications

Luminance Source	VDT Viewing Significance ^a	Application ^b	Average Initial Luminaire Luminance Option ^c				Maximum Initial Luminaire Candlepower Option ^d
			VDT Monitor Screen Reflection Properties				
			Medium-to-good ^a CSA/ISO Types I and II Monitors		Poor ^a CSA/ISO Type III Monitors		
Luminaires (direct component)	Secondary	- Industrial	≤2570 cd/m ² at 65° and above				NA
		- Conference Room	≤1715 cd/m ² at 65° and above				300 cd @65°, 185 cd @75°, 60 cd @85°
		- Transitional Space	≤1500 cd/m ² at 65° and above				300 cd @65°, 185 cd @75°, 60 cd @85°
	Normal	- Classroom	≤1500 cd/m ² at 65° and above	≤1000 cd/m ² at 65° and above	≤500 cd/m ² at 65° and above	≤200 cd/m ² at 65° and above	300 cd @65°, 185 cd @75°, 60 cd @85°
		- High-tech Industrial	≤1500 cd/m ² at 65° and above	≤1000 cd/m ² at 65° and above	≤500 cd/m ² at 65° and above	≤200 cd/m ² at 65° and above	300 cd @65°, 185 cd @75°, 60 cd @85°
	High	- Call Centers	≤1500 cd/m ² at 55° and above	≤1000 cd/m ² at 55° and above	≤500 cd/m ² at 55° and above	≤200 cd/m ² at 55° and above	300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°
		- Programming ^f	≤1500 cd/m ² at 55° and above	≤1000 cd/m ² at 55° and above	≤500 cd/m ² at 55° and above	≤200 cd/m ² at 55° and above	300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°
	Critical	- Air Traffic Control	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°
		- CAD	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°
		- Programming ^g	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°
- Command Centers		≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°	
- Medical Lab		≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°	
- Monitoring	≤200 cd/m ² at 55° and above				300 cd @55°, 220 cd @65°, 135 cd @75°, 45 cd @85°		
Daylight Media	Secondary	- Conference Room	≤3425 cd/m ²				
		- Transitional Space	≤3425 cd/m ²				
	Normal	- Industrial	≤2570 cd/m ²				
		- Office	≤855 cd/m ²				
Critical	- Office	≤615 cd/m ²					

Photometry – 4000K CCT

Report number¹: G2012327
 Catalog number: CFS22GPG28L40ULAG
 Delivered lumens: 2820
 Color²: 4000K
 Input watts: 46.8
 Efficacy: 60.3 lm/w
 CRI: 83.8
 Lamp: LED
 Luminaire: Coffaire recessed LED
 CIE Type: Direct
 Plane: 0-Deg. 90-Deg.
 Spacing criteria: 1.2 1.3
 Plane: 0-Deg. 90-Deg.
 Luminous length: 23.040 23.040

Candela distribution

Vertical Angle	Horizontal Angle			Zonal Lumens
	0°	45°	90°	
0	1020	1020	1020	
5	1012	1014	1018	96
15	958	972	987	274
25	865	895	929	413
35	740	791	846	496
45	594	666	738	513
55	428	522	602	463
65	258	361	413	344
75	128	172	201	173
85	28	35	36	40
90	3	3	3	

¹ Tested using absolute photometry as specified in LM79: IESNA Approved Method for the Electrical and Photometric Measurements of Solid State Lighting Products.
² Correlated Color Temperature within specs as defined in ANSI, NEMA, ANSLG C78 377-2008: Specifications for the Chromaticity of Solid State Lighting Products.

Coefficients of utilization

Ceiling	80%			50%			30%		
	70	50	30	50	30	10	50	30	10
Wall	Zonal Cavity Method								
RC	Effective Floor Reflectance = 20%								
RW									
1	109	104	100	98	95	92	94	91	89
2	99	91	84	86	80	76	82	78	74
3	90	80	72	75	69	64	73	67	62
4	83	71	62	67	60	54	65	58	53
5	76	63	54	60	53	47	58	51	46
6	70	57	48	54	47	41	52	46	41
7	65	52	43	49	42	36	48	41	36
8	61	47	39	45	38	32	44	37	32
9	57	43	35	41	34	29	40	34	29
10	53	40	32	38	31	27	37	31	26

Zonal lumen summary*

Zone	Lumens	% Lamp	% Fixt.
0-30	784	27.8	27.8
0-40	1280	45.4	45.4
0-60	2256	80.0	80.0
0-90	2820	100.0	100.0
90-180	0	0	0
0-180	2820	100.0	100.0

*Total Efficiency

Avg. Luminance (cd/m²)

Vertical Angle	Horizontal Angle		
	0°	45°	90°
45	2452	2749	3046
55	2178	2656	3063
65	1782	2493	2852
75	1444	1940	2267
85	938	1172	1206

Table 12.4 | Default Luminance and Luminaire Intensity Recommendations for VDT Applications

Luminance Source	VDT Viewing Significance ^a	Application ^b	Average Initial Luminaire Luminance Option ^c		Maximum Initial Luminaire Candlepower Option ^d	
			Medium-to-good ^e CSA/ISO Types I and II Monitors	Poor ^f CSA/ISO Type III Monitors	Luminaire Candlepower Limits	
Room Surfaces	Secondary		≤1715 cd/m ²		CSA/ISO Types I and II Monitors: 1065 1275 1065 1275 1680 1100 1680 1100	
	Normal		≤855 cd/m ²		CSA/ISO Type III Monitors: 980 640 980 640 840 550 840 550	
	High		≤615 cd/m ²		Typical Spacing of Uplights: 8 ft 12 ft 8 ft 12 ft 8 ft 12 ft 8 ft 12 ft	
	Critical		≤615 cd/m ²		values below are rates of change in units of cd/m ² per meter of ceiling surface—this constitutes the recommended maximum change in luminance over a meter of ceiling based on the luminance ratios cited in Table 12.5 to minimize veiling reflections	
Daylight Media	Secondary	- Conference Room - Transitional Space	≤3425 cd/m ²			
	Normal	- Industrial	≤2570 cd/m ²			
	High		≤855 cd/m ²			
	Critical		≤615 cd/m ²			

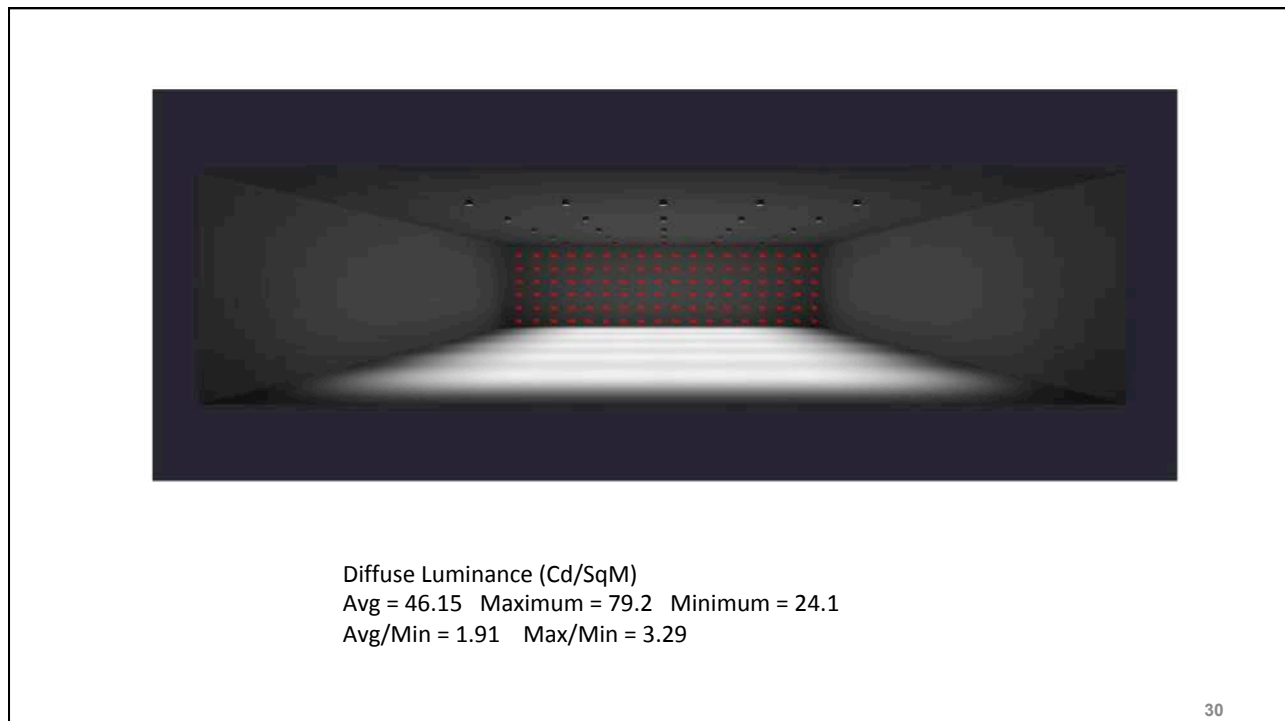
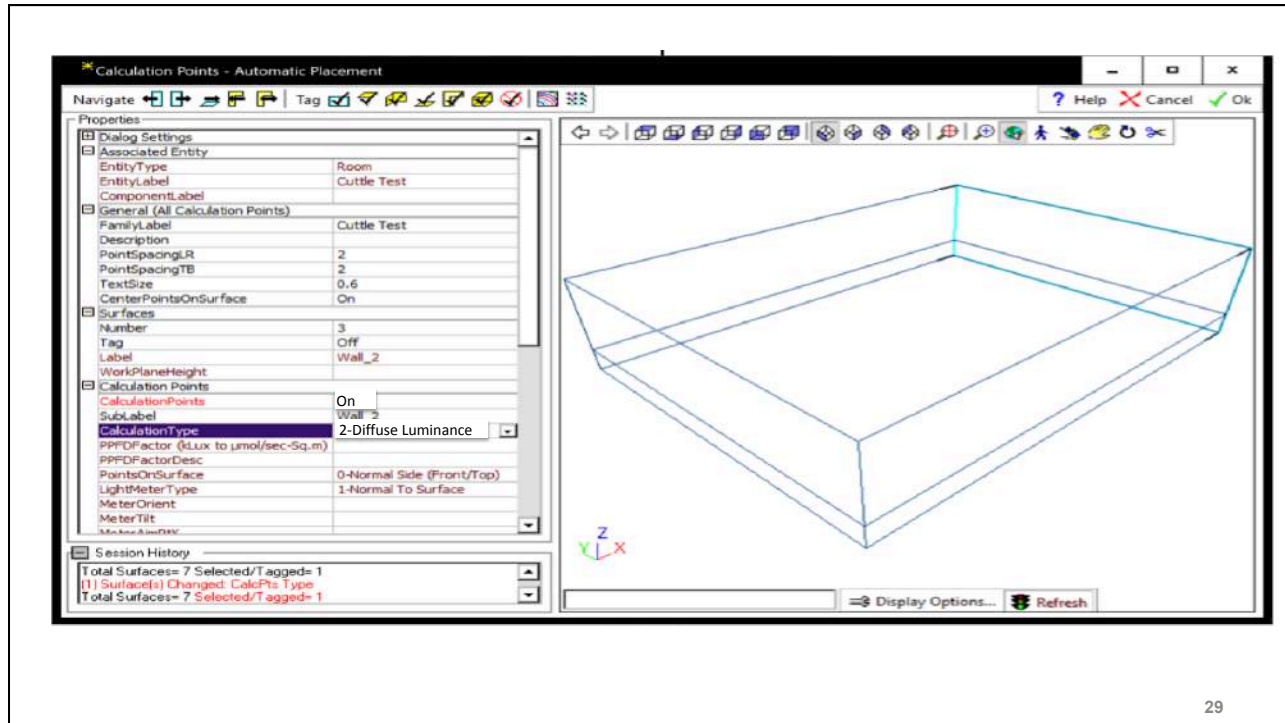


Table 22.1 Common Applications Lighting Checklist	
Topics ✓ Criteria and Design Resources	
Accenting 15.1.1.3 Accent Lighting Table 12.2 Subjective Impressions Table 15.2 Accent Illuminance Ratios Table 22.1 Common Applications Illuminance Recommendations	
Appearance 12.2 Spatial Factors	
Color 12.5.6 Color Considerations	
Controls 16 LIGHTING CONTROLS	
Daylighting 14 DESIGNING DAYLIGHTING	
Electric Lighting 15 DESIGNING ELECTRIC LIGHTING	
Flicker 4.6 Flicker and Temporal Contrast Sensitivity	
Glare 4.10.1 Discomfort Glare 4.10.3 Disability Glare	
Illuminance This Chapter: Table 22.2	
Illuminance Table 12.6 Default Illuminance Ratio Recommendations Figure 12.22 Task Coverage Example	
Light Distribution 12.3.2 Subjective Impressions	
Luminances 12.5.2 Luminance Table 12.5 Default Luminance Ratio Recommendations	
Maintenance 15.4.4 Installation and Maintenance	
Nighttime Outdoor Environment Table 15.6 Nighttime Operational Strategies for Improved Outdoor Environmental Regard	
Systems Integration 12.6 Systems Factors	
Veiling Reflections This Chapter: Section 22.3.6 12.5.4 Veiling Reflections	
Visual Tasks This Chapter: Section 22.2 This Chapter: Table 22.2 Table 11.2 Programming: Inventory Scope and Specific Examples 12.5.1 Visual Tasks Table 12.3 Sample Visual Task Survey	

Table 12.5 | Default Luminance Ratio Recommendations

Intent	Areas of Interest	Maximum Luminance Ratio ^a
Maintain task attention	• Paper task to VDT screen	
	• paper to negative-polarity VDT screen	3:1
	• paper to positive-polarity VDT screen	1:3
	• Task to immediate background surfaces	3:1
	• Task to distant background	
	• task to dimmer distant background	10:1
	• task to brighter distant background	1:10
	ceiling and/or wall zone	
	• All CSA/ISO I and II positive polarity monitors • CSA/ISO I and II negative polarity monitors in normal/secondary situations • brighter ceiling and/or wall zone to dimmer ceiling and/or wall zone	8:1

Luminance Ratio Calculation

1. Create task (e.g., planar object = paper task, reflectance = 65%)
2. Place luminance calculation points on task surface(s)
3. Place luminance calculation points on immediate background
4. Again, generate luminances of all room surfaces, task, and immediate surround
5. Compute ratios and compare to figure 12.5

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Table 12.5 | Default Luminance Ratio Recommendations

Intent	Area of Interest	Maximum Luminance Ratio ^a
Maintain visual comfort	Task to light source	
	• task to daylight media	1:40
	• task to luminaires	1:40
	Light-source-adjacent-surfaces to light source	
	• daylight-media-adjacent-surfaces to daylight media	1:20
	• luminaire-adjacent-surfaces to luminaires	1:20
Minimize veiling reflections	All CSA/ISO III monitors	
	CSA/ISO I and II negative polarity monitors in critical/high situations	
	• brighter ceiling and/or wall zone to dimmer ceiling and/or wall zone	4:1
	All CSA/ISO I and II positive polarity monitors	
CSA/ISO I and II negative polarity monitors in normal/secondary situations		
	• brighter ceiling and/or wall zone to dimmer ceiling and/or wall zone	8:1

Table 22.1 | Common Applications Lighting Checklist

Topics	
✓ Criteria and Design Resources	
Accenting	15.1.1.3 Accent Lighting Table 12.2 Subjective Impressions Table 15.2 Accent Illuminance Ratios Table 22.1 Common Applications Illuminance Recommendations
Appearance	12.2 Spatial Factors
Color	12.5.6 Color Considerations
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Daylighting	14 DESIGNING DAYLIGHTING
Electric Lighting	15 DESIGNING ELECTRIC LIGHTING
Flicker	4.6 Flicker and Temporal Contrast Sensitivity
Glare	4.10.1 Discomfort Glare 4.10.3 Disability Glare
Illuminance	This Chapter: Table 22.2

Illuminance

Table 12.6 | Default Illuminance Ratio Recommendations
 Figure 12.22 | Task Coverage Example

Light Distribution

12.3.2 Subjective Impressions

Luminances

12.5.2 Luminance
 Table 12.5 | Default Luminance Ratio Recommendations

Maintenance

15.4.4 Installation and Maintenance

Nighttime Outdoor Environment

Table 15.6 | Nighttime Operational Strategies for Improved Outdoor Environmental Regard

Systems Integration

12.6 Systems Factors

Veiling Reflections

This Chapter: Section 22.3.6
 12.5.4 Veiling Reflections

Visual Tasks

This Chapter: Section 22.2
This Chapter: Table 22.2
 Table 11.2 | Programming: Inventory Scope and Specific Examples
 12.5.1 Visual Tasks
 Table 12.3 | Sample Visual Task Survey

Table 15.2 | Accent Illuminance Ratios

Attraction	Role	Focal-point Reflectance	Illuminance Ratio ^a	Application Notes ^b	Example Applications
Strong	Dominant	≥50% <50%	~20:1 focal-point-to-task ~40:1 focal-point-to-task	Used very sparingly for short duration on one or a few relatively small focal points for momentous occasion or experience. Long-term exposure may fade/degrade focal. Focal point lighted to these ratios may be a fraction of total focal area. Focal plane may be different from task plane.	<ul style="list-style-type: none"> House of Worship: reverent focal element during dark-house ceremony Retail: highly-exclusive indoor small displays such as an extraordinary piece of jewelry
	Dramatic	≥50% <50%	~10:1 focal-point-to-task ~20:1 focal-point-to-task	Used sparingly on one or several focal areas for significant effect. Long-term exposure may fade/degrade focals. Focal point lighted to these ratios may be a fraction of total focal area. Focal plane may be different from task plane.	<ul style="list-style-type: none"> Corporate and hospitality lobbies: exclusive wall materials such as granite Retail: exclusive indoor display such as vignette at department or store entry
Moderate	Feature	≥50% <50%	~5:1 focal-point-to-task ~10:1 focal-point-to-task	Used on focal points for visual attention. Focal point lighted to these ratios may be a fraction of total focal area. Long-term exposure may fade/degrade focals. Focal plane may be different from task plane.	<ul style="list-style-type: none"> Hospitality: destination features such as concierge, front desk, wall-material features Retail: dazzle and highlight of feature displays

Table 15.2 | Accent Illuminance Ratios

Attraction	Role	Focal-point Reflectance	Illuminance Ratio ^a	Application Notes ^b	Example Applications
Soft	Visual Edge	≥50%	~2:1 focal-point-to-task	Used on focal points or features for visual interest. Long-term exposure may fade/degrade focals. Focal plane may be different from task plane.	<ul style="list-style-type: none"> • Conference rooms: artwork, wall-material features • Contemporary residences: artwork • Reception: artwork, wall-material features
		<50%	~5:1 focal-point-to-task		
Subtle	Visual Relief	≥50%	~1:1 focal-point-to-task	Used liberally on focal points for visual relief. Long-term exposure may fade/degrade focals. Focal plane may be different from task plane.	<ul style="list-style-type: none"> • Office: artwork, wall-material features • Traditional residences: artwork
		<50%	~2:1 focal-point-to-task		

a. Ratio of E_v (average illuminance on focal point typically of vertical orientation) to E_h (average illuminance on primary task plane typically of horizontal orientation).

b. See 21 | LIGHTING FOR ART for criteria related to preservation-worthy objects.

Designing with Luminance and Exitance

1. Lighting Design Approaches
2. Designing with Luminance
3. Designing with Exitance
4. Measuring Luminance and Exitance in the Field

Cuttle: Mean Room Surface Exitance

- In the 21st century when most things that need to be seen have been designed to be seen, the function of general lighting in most spaces should shift from providing an amount of light related to task difficulty to providing an amount of light that meets the expectations of most occupants in appearing **adequately bright or dim**.
- For designers, Cuttle proposes a change in design approach from specifying levels of illuminance for task to providing levels of light that yield predictable assessments of **surrounding brightness** on a scale that runs from distinctly bright on the upper end to very dim on the lower.
- Perceived Adequacy of Illumination [**PAI**] is a binary judgement of whether or not the illumination is adequately bright or dim for a specific use.
- Mean Room Surface Exitance [**MRSE**], as a measure of the overall density of inter-reflected flux within a space, has been proposed as a reliable indicator of **surrounding brightness** and, for the purposes of design guidelines and standards, that correlates with **PAI**.

MRSE (lm/m ²)	Perceived Brightness
10	Lowest level for color discrimination
30	Dim appearance
100	Lowest level for 'acceptably bright' appearance
300	Bright appearance
1000	Distinctly bright appearance

Cuttle's proposed range of subjective assessments of lit appearance related to MRSE.

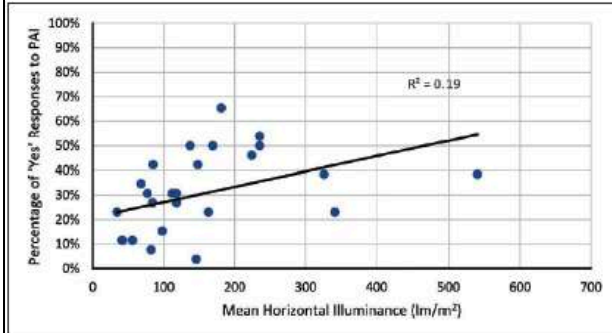


Figure 8 – Yes responses to PAI against Horizontal Illuminance.

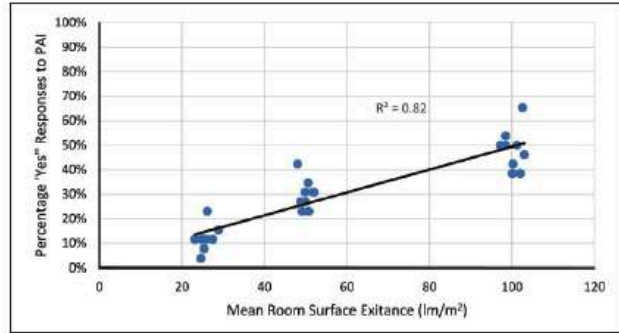


Figure 9 – Yes responses for varying levels of MRSE against PAI.

Duff J, Kelly K, Cuttle C. (2017) Spatial brightness, horizontal illuminance and mean room surface exitance in a lighting booth. *Lighting Research and Technology*; 49(1): 5-15.

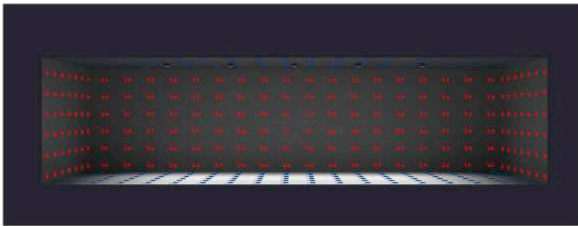
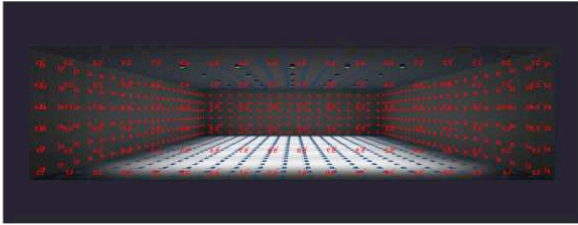
2018 Annual Conference

August 9 -11 | Westin Boston Waterfront | Boston, MA

Surface Exitance: Approach, Method + Analysis

Sean Casey, Parsons School of Design + Tillotson Design Associates

Dr. Craig Bernecker, The Lighting Education Institute + Parsons School of Design



Ceiling Exitance (Lms/SqM)
 Average = 4.14 Maximum = 6.7 Minimum = 1.2 Avg/Min = 3.45 Max/Min = 5.58

East Wall Exitance (Lms/SqM)
 Average = 4.02 Maximum = 6.1 Minimum = 1.2 Avg/Min = 3.35 Max/Min = 5.08

Floor Exitance (Lms/SqM)
 Average = 48.59 Maximum = 91.1 Minimum = 0.5 Avg/Min = 97.18 Max/Min = 182.20

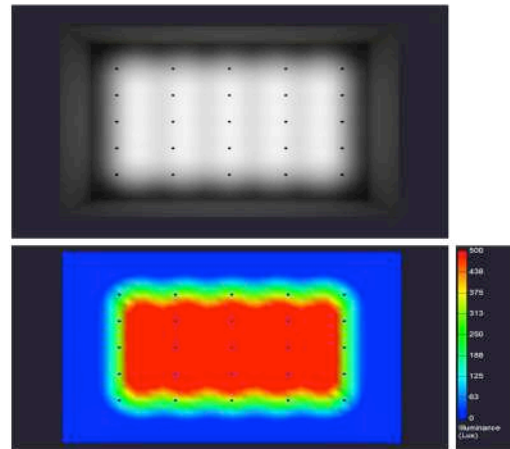
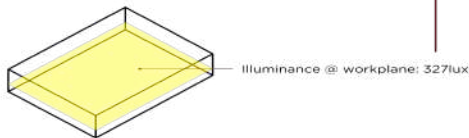
North Wall Exitance (Lms/SqM)
 Average = 4.14 Maximum = 5.9 Minimum = 1.3 Avg/Min = 3.18 Max/Min = 4.54

South Wall Exitance (Lms/SqM)
 Average = 4.07 Maximum = 5.8 Minimum = 1.3 Avg/Min = 3.13 Max/Min = 4.46

West Wall Exitance (Lms/SqM)
 Average = 4.07 Maximum = 6.2 Minimum = 1.2 Avg/Min = 3.39 Max/Min = 5.17

An exitance calculation grid is placed on all enclosing surfaces.

Surface	Avg. Exitance (lm/m ²)	Surface Area (m ²)	Total Surface Lumens
Ceiling	4.14	108	447.12
Floor	48.59	108	5247.72
North Wall	4.14	36	149.04
East Wall	4.02	27	108.54
South Wall	4.07	36	146.52
West Wall	4.07	27	109.89
		Total Surface Area: 342m ²	Total Spatial Lumens: 6208.85
		Total Surface Lumens/ Total Surface Area	Mean Exitance: 18.15



From the mean exitance of a single surfaces to the mean exitance of all enclosing surfaces. Calculating the diffused field of inter-reflected flux within the volume of a space.

MRSE (lm/m ²)	Perceived Brightness
10	Lowest level for color discrimination
30	Dim appearance
100	Lowest level for 'acceptably bright' appearance
300	Bright appearance
1000	Distinctly bright appearance

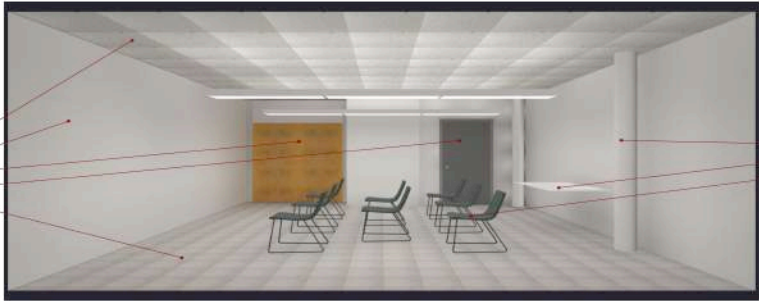
Cuttle's proposed range of subjective assessments of lit appearance related to MRSE.

Room Surface Reflectance Values

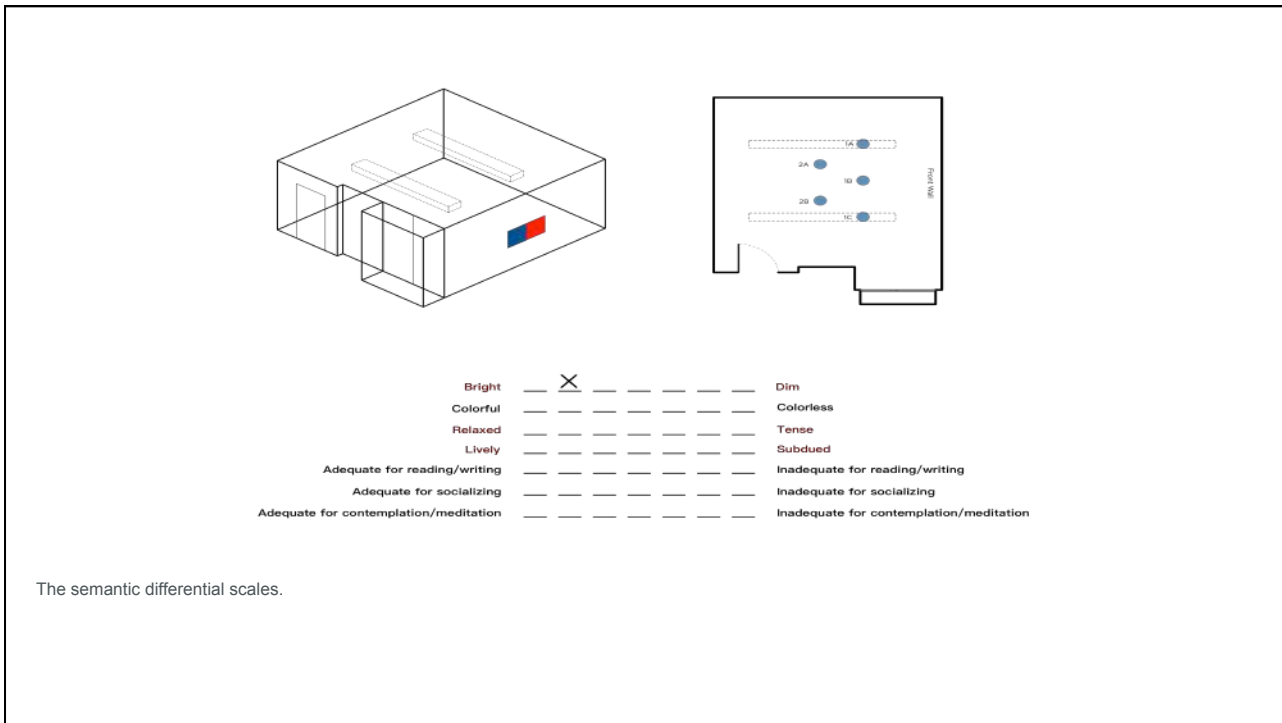
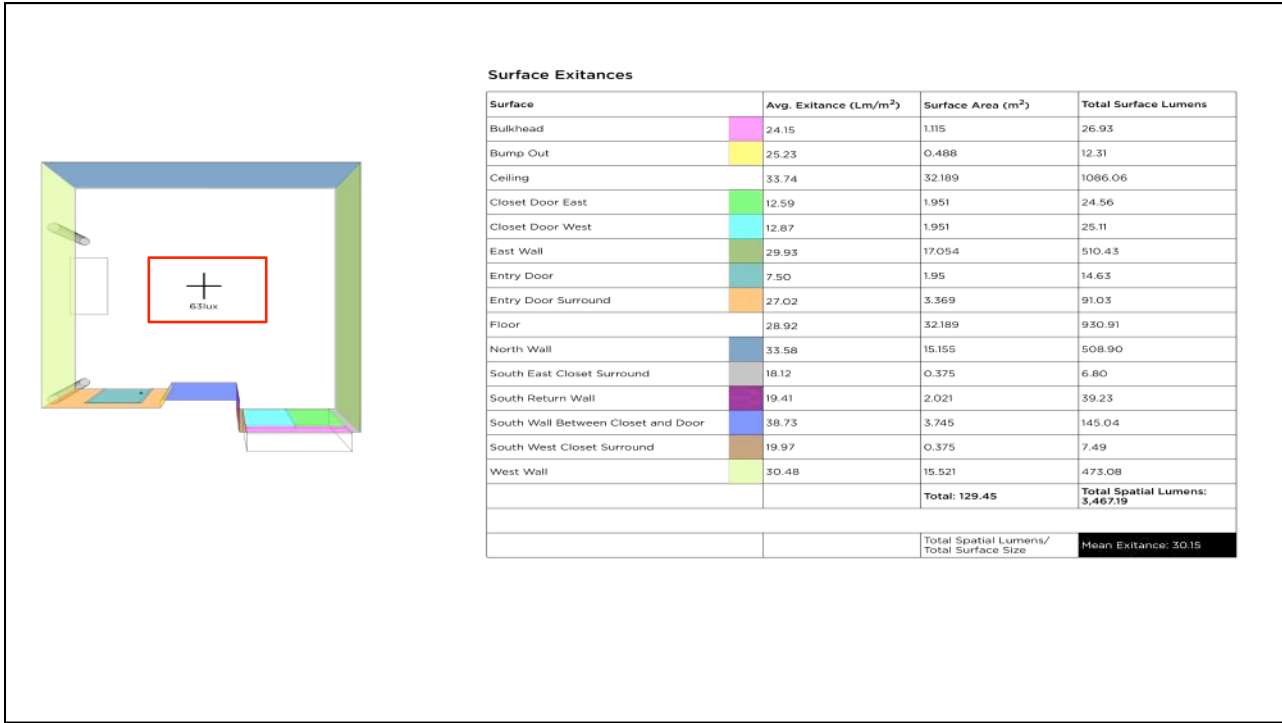
Ceiling	0.64
Wall	0.93
Closet Door	0.44
Entry Door	0.22
Floor	0.63

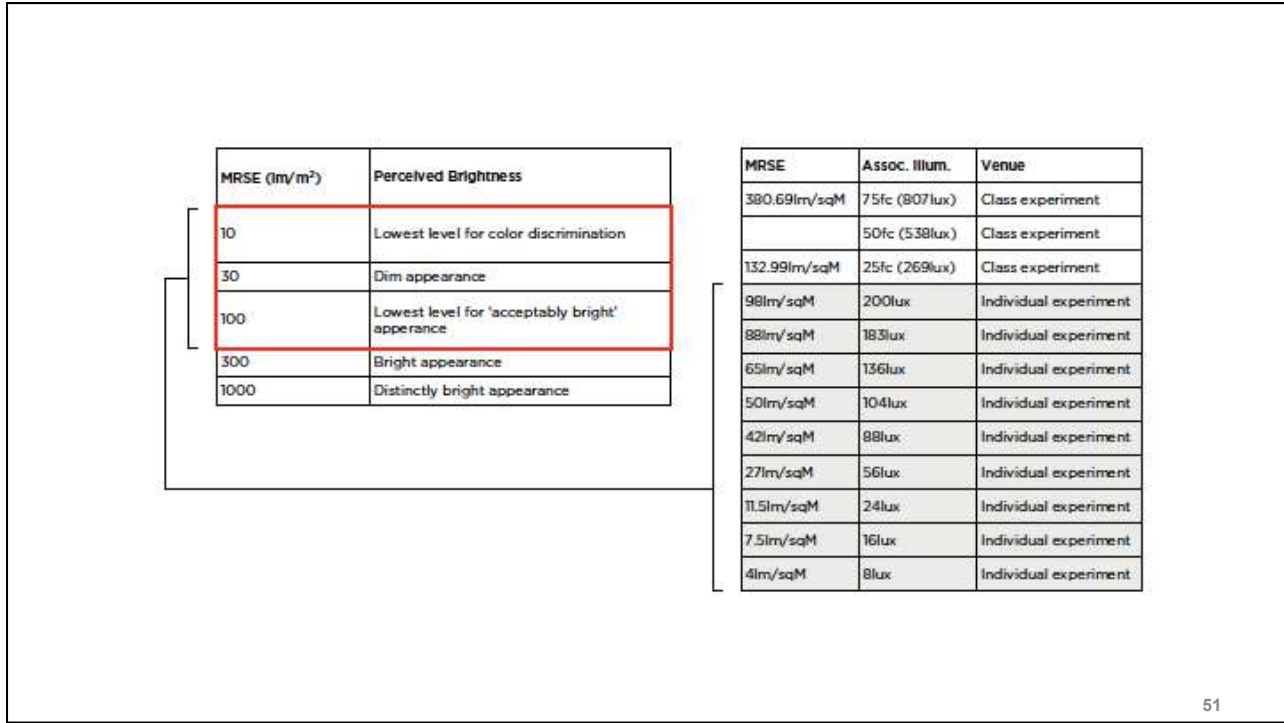
Object Surface Reflectance Values

Column	0.93
Table	0.88
Chair	0.15



Modeling the test site.





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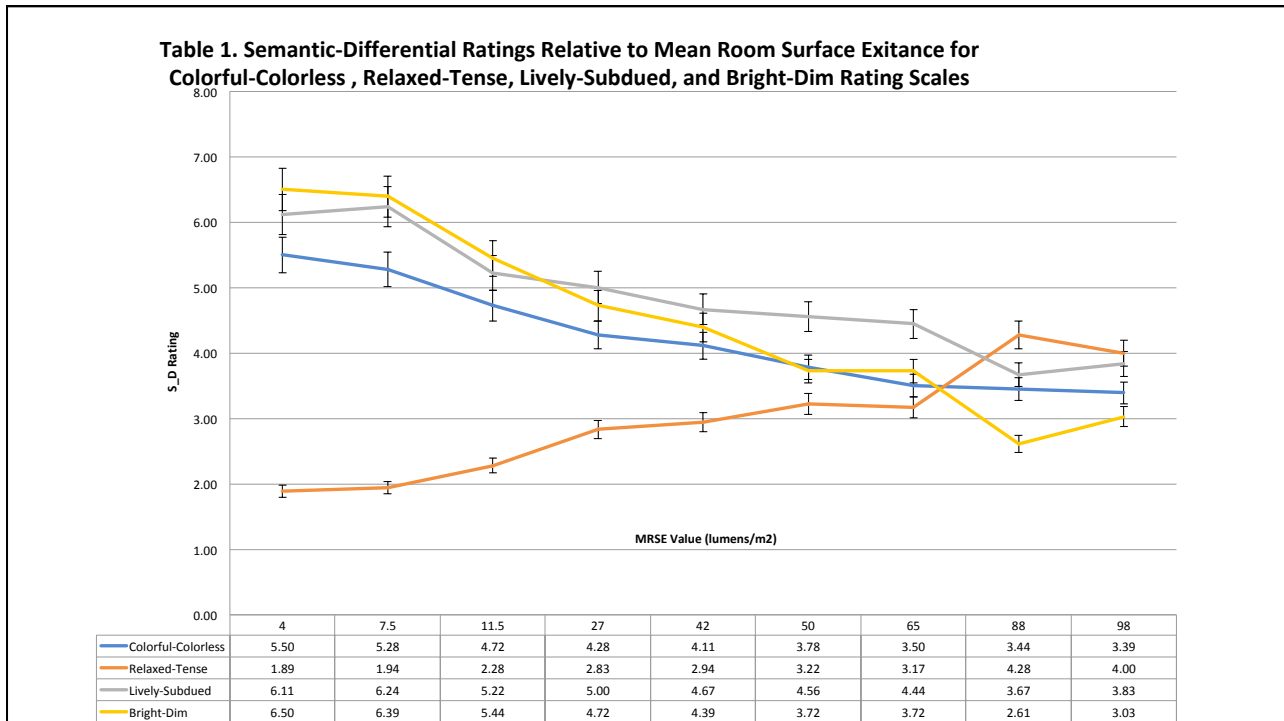
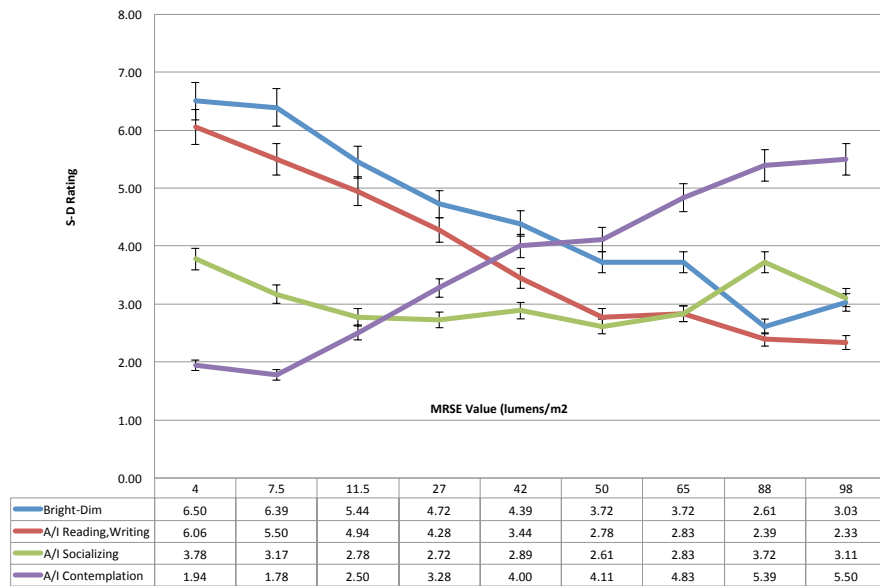


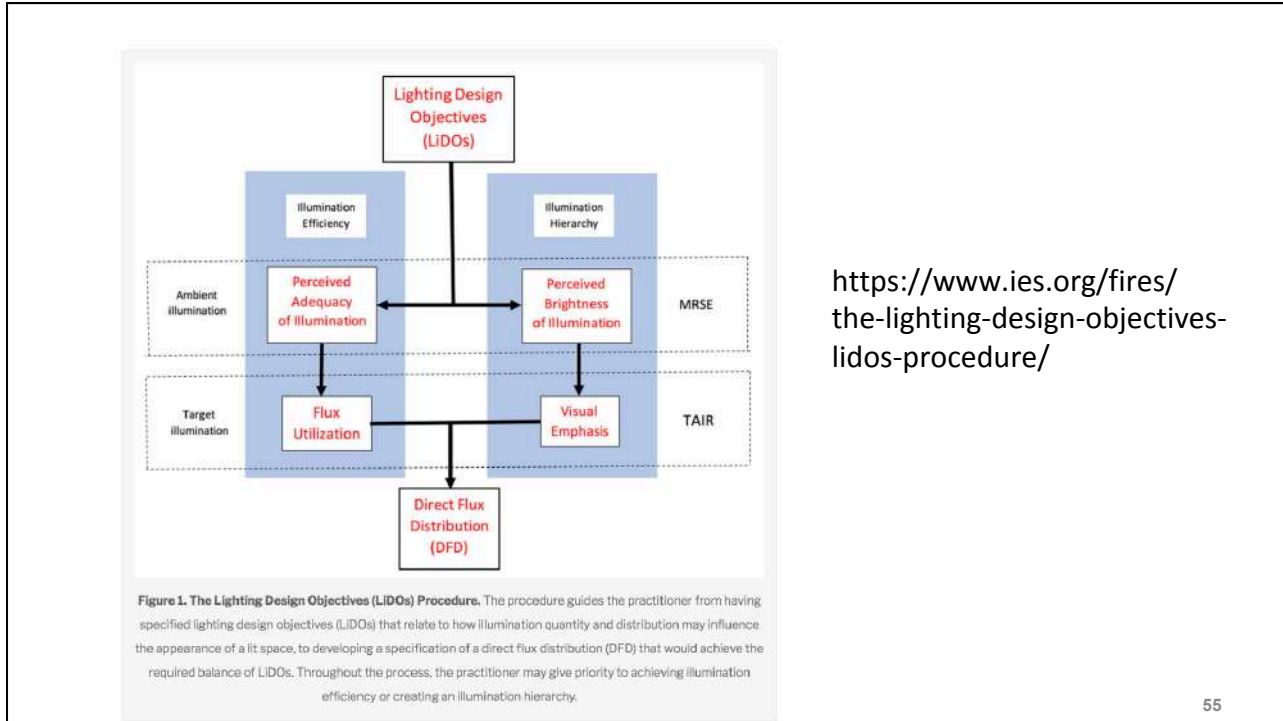
Table 2. Semantic-Differential Ratings Relative to Mean Room Surface Exitance for Bright-Dim Rating Scale and Adequate-Inadequate for Reading-Writing, Socializing and Contemplation Scales



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MRSE (lm/m ²)	Perceived Brightness
10	Lowest level for color discrimination
30	Dim appearance
100	Lowest level for 'acceptably bright' appearance
300	Bright appearance
1000	Distinctly bright appearance

MRSE (lm/m ²)	Perceived Brightness
5	Lowest level for color discrimination
4-20	Adequate for Contemplation + Meditation
- 30	Subdued Atmosphere
30	Dim appearance
- 65	Relaxed Atmosphere
50+	Adequate for Reading + Writing (Short Duration)
100	Lowest level for 'acceptably bright' appearance



<https://www.ies.org/fires/the-lighting-design-objectives-lidos-procedure/>

Perceived Brightness of Illumination (PBI)	MRSE (lm/m ²)
Bright	150
Slightly bright	120
Neither dim nor bright	90
Slightly dim	60
Dim	30

Table 1. Tentatively Proposed PBI/MRSE Relationship.

Visual Emphasis (VE)	TAIR
Emphatic	40
Strong	10
Distinct	3
Noticeable	1.5
Absent	1.0

Table 2. Tentatively Proposed Visual Emphasis/Target-Ambient Illuminance Ratio Relationship.

Designing with Luminance and Exitance

1. Lighting Design Approaches
2. Designing with Luminance
3. Designing with Exitance
4. **Measuring Luminance and Exitance in the Field**

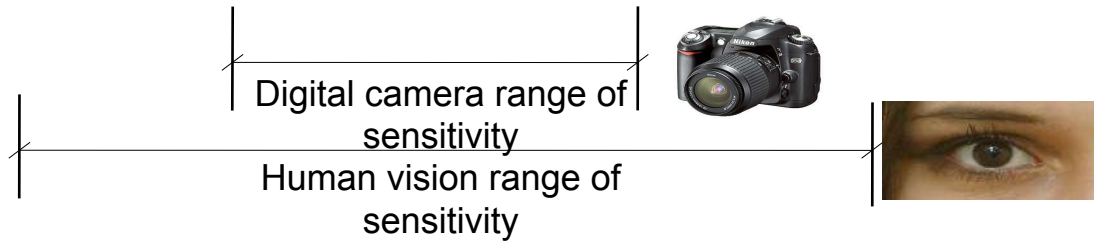
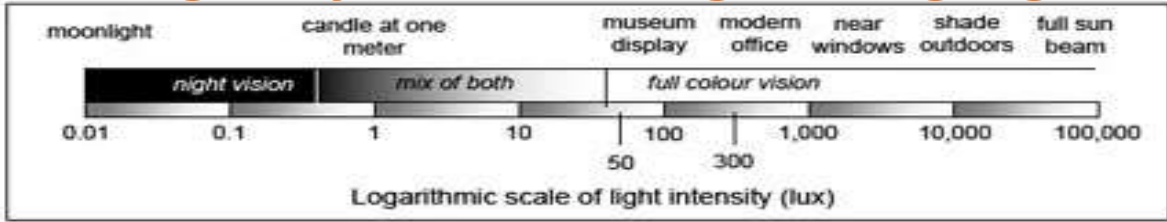
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High Dynamic Range Imaging

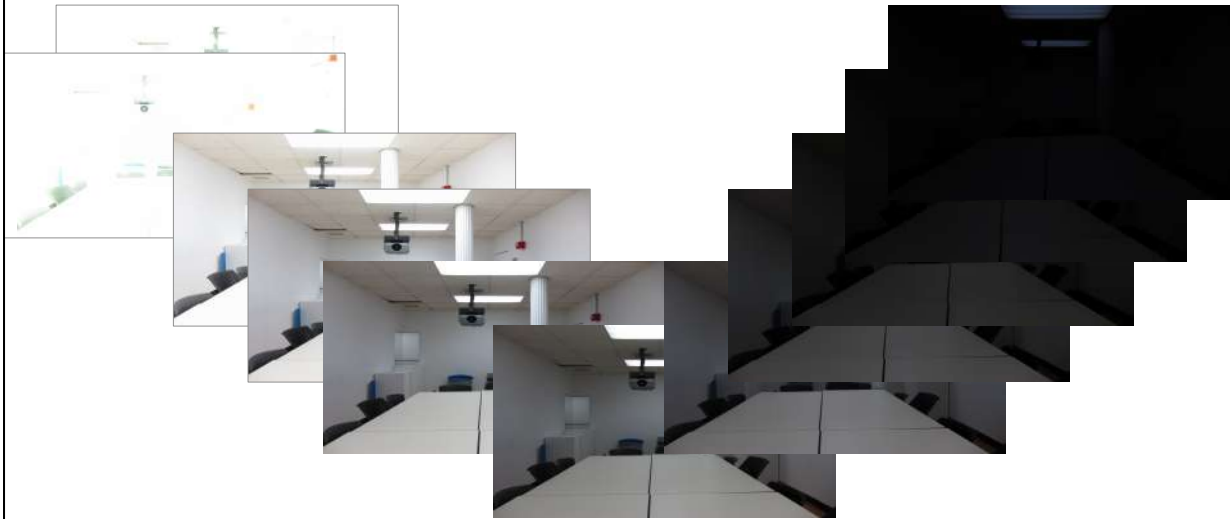


Digital Camera

High Dynamic Range Imaging



High Dynamic Range Imaging



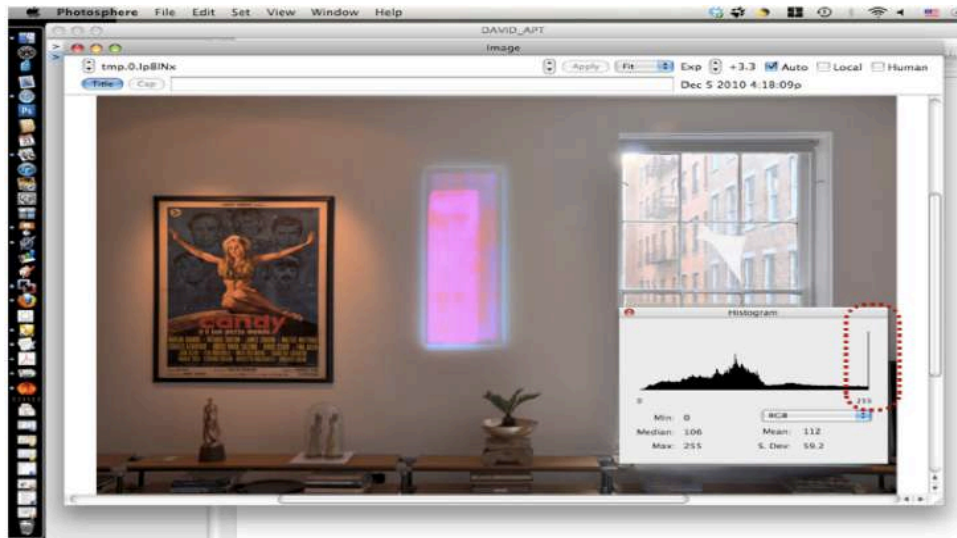
- HDR Requirements (what you typically need):

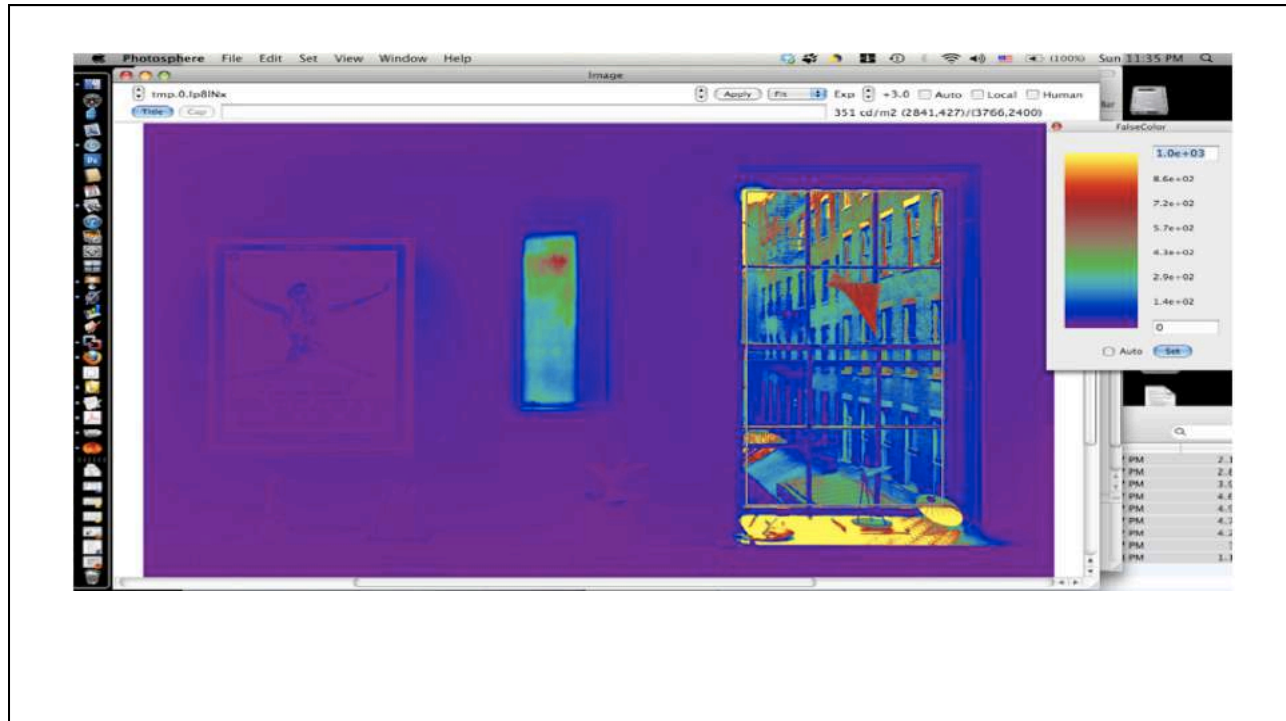


Digital camera with variable shutter speed and good tripod

Luminance Meter and Gray Card for Calibration

HDR Software & Laptop
Photosphere version 1.8.6U,
Copyright 2010
Greg Ward, Anywhere Software





Opportunities:

- Explore interpretation of human responses to entire visual field to inform design recommendations
 - Assessment of brightness and glare
 - Assessment of uniformity ratios and perception of uniformity across a surface
 - Validation of photorealistic renderings
 - Exploration of psychological responses to lighting (Flynn Modes)

Benefits:

- Relatively simple, widely-available technology for capturing a large quantity of lighting measurements
- No longer solely reliant on illuminance as *the* quantitative design metric (enable luminance- based design recommendations)
- Implications for energy codes to enable a true evaluation of quality of lighting system

Table 12.2 | Subjective Impressions

Impression	Lighting Modes ^{a,b,c}	Design Implications	Example Reinforcing Techniques ^d	Typical Applications
Preference	<ul style="list-style-type: none"> - Perimeter - Nonuniform - Bright 	<ul style="list-style-type: none"> - Use perimeter nonuniform lighting. Brighter effects help, but not necessary. 	<ul style="list-style-type: none"> - A window wall or accenting a wall <p>AND</p> <ul style="list-style-type: none"> - Accenting wall art or accenting one or several architectural or material features and/or using decorative lighting, such as pendants, sconces, or table or floor lights placed intermittently around edges of room or area 	<ul style="list-style-type: none"> - Most spaces - See Figure 12.12 - See Figure 12.13
Privacy	<ul style="list-style-type: none"> - Nonuniform - Dim - Perimeter 	<ul style="list-style-type: none"> - Use nonuniform relatively dim lighting. Emphasis at periphery helps, but not necessary. 	<ul style="list-style-type: none"> - Dim and somewhat spotty lighting effects from downlighting or using dim decorative lighting, such as pendants, sconces, or table or floor lights 	<ul style="list-style-type: none"> - Upscale clubs - Upscale restaurants - Some residential spaces - Meditation spaces - See Figure 12.13
Relaxation	<ul style="list-style-type: none"> - Perimeter - Nonuniform - Dim 	<ul style="list-style-type: none"> - Use perimeter nonuniform lighting. Dimmer effects help, but not necessary. 	<ul style="list-style-type: none"> - Wallwashing one or two darker-toned walls or features or dim wallwashing one or two lighter-toned walls or features <p>AND</p> <ul style="list-style-type: none"> - Softly accenting select art and/or several architectural or material features and/or using decorative lighting, such as pendants, sconces, or table or floor lights placed intermittently around edges of room or area 	<ul style="list-style-type: none"> - Casual areas - Conference rooms - Lounges - Sit-down restaurants - Waiting areas
Spaciousness	<ul style="list-style-type: none"> - Uniform - Perimeter - Bright 	<ul style="list-style-type: none"> - Use uniform wall lighting. Brighter effects help, but not necessary. 	<ul style="list-style-type: none"> - Window walls for at least two walls and/or wallwashing at least two walls; consider wall reflectances of 60% or more for at least half the walls to be lighted 	<ul style="list-style-type: none"> - Circulation - Assembly spaces - See Figure 12.14
Visual Clarity	<ul style="list-style-type: none"> - Bright - Perimeter - Uniform 	<ul style="list-style-type: none"> - Create bright ceiling and worksurfaces with some emphasis on periphery. Uniform effects help, but not necessary. 	<ul style="list-style-type: none"> - Skylights, relatively bright recessed lensed modular luminaires, recessed direct/indirect modular luminaires, or downlighting mixed with uplighting; consider ceiling reflectances of 90% <p>AND</p> <ul style="list-style-type: none"> - Window walls and/or wallwashing 	<ul style="list-style-type: none"> - Work spaces - See Figure 12.15

a. Lighting modes are listed in order of most influential first.

b. Dim and bright are used in a relative sense. No quantitative design values are available. Surface reflectances affect senses of dim and bright.

c. Nonuniform as used here means that the patterns of light are applied intermittently, but not in a completely random or haphazard manner. Uniform indicates that the pattern or patterns of light are consistently or regularly arranged.

d. Daylight or electric light can be employed to achieve reinforcing techniques. Subjective impressions' techniques are combined with other lighting techniques as necessary to meet other design criteria.

Designing with Luminance and Exitance

Learning Objectives

Participants will be able to:

1. Identify luminance design criteria
2. Recognize tools for evaluating luminance design criteria
3. Compare illuminance and exitance as measures of perceived adequacy of illumination
4. Recognize tools for the analysis of mean room surface exitance

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“I believe light is the maker of all material. Material is spent light.” - Louis Kahn



This concludes The American Institute of Architects Continuing
Education Systems Course



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