Designers Lighting Forum

Practical Application of Circadian Metrics

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Borealis Lighting Studio

Wednesday 10.30-11.30

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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

Learning Objectives

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

1. Understand the issues of circadian strategies in healthcare
2. Identify areas of application for circadian lighting
3. Interpret differences between key circadian metrics
4. Apply a range of circadian metric calculation methods to healthcare environments

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Healthcare & Circadian Needs

Healthcare Industry 2030

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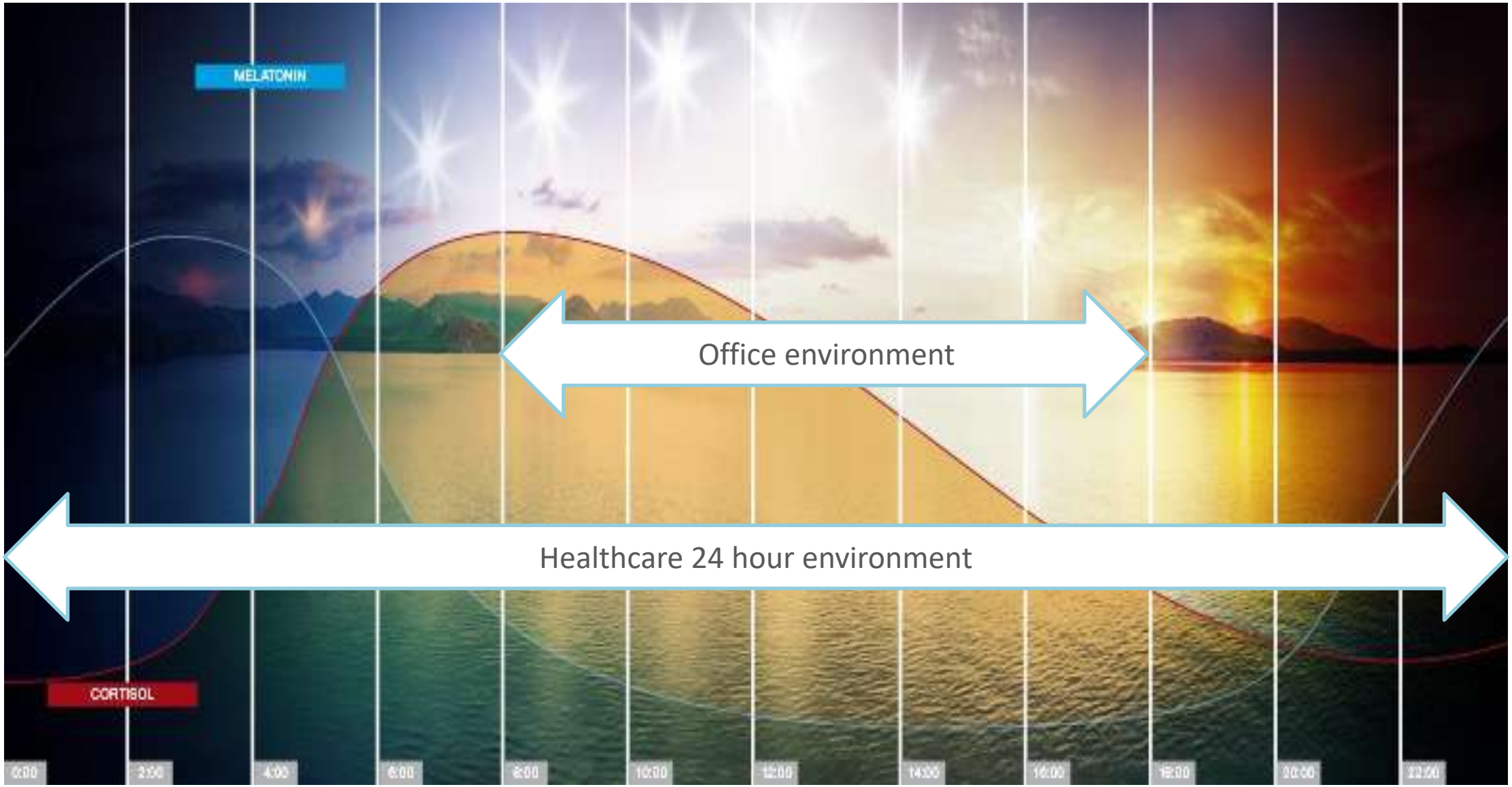
Designing for the 24 hour environment



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Who Are We Designing For?

Patients V Carers











Who Are We Designing For?

Day Active

Night Active











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Competing Light Stimulus Needs

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Competing Light Stimulus Needs

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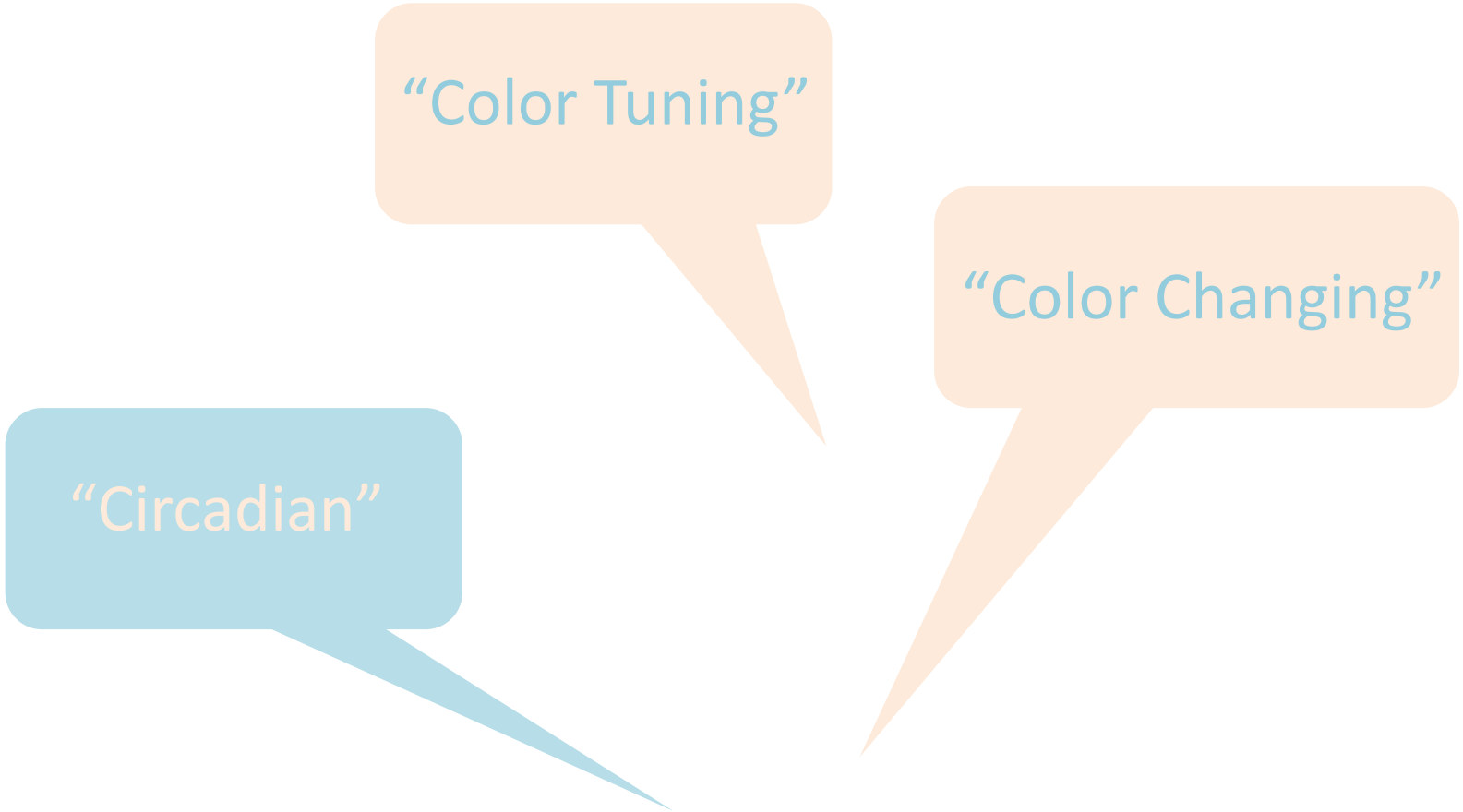
Design Factors for Circadian Impact

Color Tuning ≠ Circadian



Color Temperature

Psychophysical

V

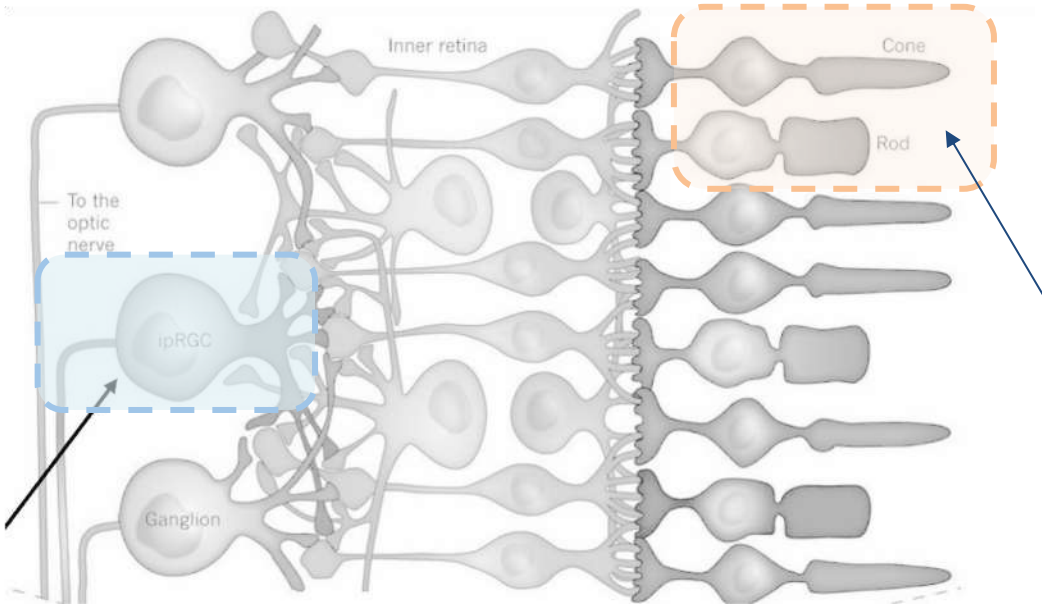
Physiological

Early Circadian Metrics Debate

Non- Visual Photoreceptors

melanopic lux
(non-visual system photoreceptors)

Equivalent Melanopic Lux (EML)
Lucas Group (Well Building)
Index of Values tied to CCT



includes only non-visual photoreceptors (ipRGCs) in calculation of EML

Visual Photoreceptors

photopic lux
(visual system photoreceptors: illuminance)

Circadian Stimulus (CS)
Lighting Research Council (LRC)
Scale 0-1

includes visual photoreceptors (rods, cones) in addition to non visual photoreceptors in calculation of CS

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Circadian Metrics

Equivalent Melanopic Lux	Melanopic Equivalent Daylight Illumination	Circadian Stimulus
EML	**MEDI**	**CS**
Non Visual Receptors Biologically active light ipRGC peak sensitivity +/- 480 nm	Non visual receptors + x Lux (amount) x daylight reference Mathematical relationship to EML	Visual and non-visual receptors

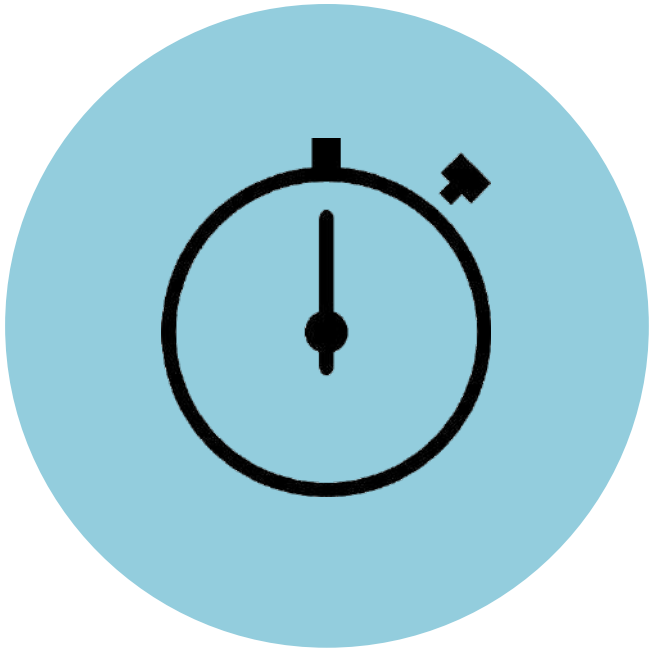
Circadian Metrics

Standard	Temporal pattern		Lighting quantity (Note: these are a function of light level and spectrum)				Location
	Timing of exposure	Duration of exposure	Circadian stimulus (CS) (Percent)	Equivalent melanopic Lux (EML) (Melanopic Lux)	Melanopic equivalent daylight illuminance (Melanopic EDI) (Lux)	Photopic Illuminance (Lux)	
WELL v2.0 Requirements for 1 point	At least between the hours of 9 a.m. and 1 p.m. Light levels may be lowered after 8 p.m.	Minimum of 4 h.	≥0.30 (if electric light only)	≥150 (if electric light only) ≥120 from electric lighting (if certain daylighting criteria are met)	≥ 136 (if electric light only) ≥109 from electric lighting (if certain daylighting criteria are met)	N/A	Vertical plane at eye level
WELL v2.0 Requirements for 3 points	At least between the hours of 9 a.m. and 1 p.m. Light levels may be lowered after 8 p.m.	Minimum of 4 h.	N/A	≥240 (if electric light only) ≥180 from electric lighting (if certain daylighting criteria are met)	≥ 218 (if electric light only) ≥163 from electric lighting (if certain daylighting criteria are met)	N/A	Vertical plane at eye level
UL 24480	7 a.m.–4 p.m.	Minimum of 2 h, morning If not full period	≥0.30	Comply with WELL criteria shown above based on desire for 1 point or 3 points	N/A	≥500	Vertical plane at eye level
	5–7 p.m.	During full period	≤0.20		N/A	N/A	
	After 8 p.m.	During full period	≤0.10		N/A	N/A	

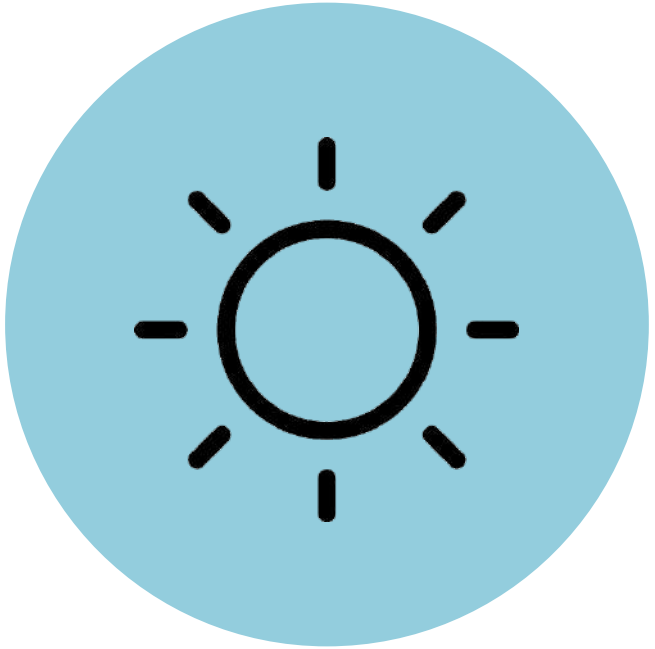
Note that where alternative compliance paths are offered, either CS, EML, EDI, or Photopic Illuminance can meet the criteria.

Design Factors

Personal Factors



Time Factors



Qualities of Light

Who Are We Designing For?

Circadian Phase Shift

Restorative Sleep

Long term Health









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Personal Factors - Chronotypes

Early Birds

V

Night Owls

Circadian phase shift












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Personal Factors - Age

Adolescents V Elderly

Delayed Sleep onset

Early Sleep onset












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Personal Factors – Lifestyle/ Culture

Shiftwork V Regular hours

Social Jetlag












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Personal Factors - Gender

Men V Women

Later / Earlier Sleep Wake Cycle
Health Issues
Susceptibility to wakefulness
Longer/ shorter intrinsic circadian period












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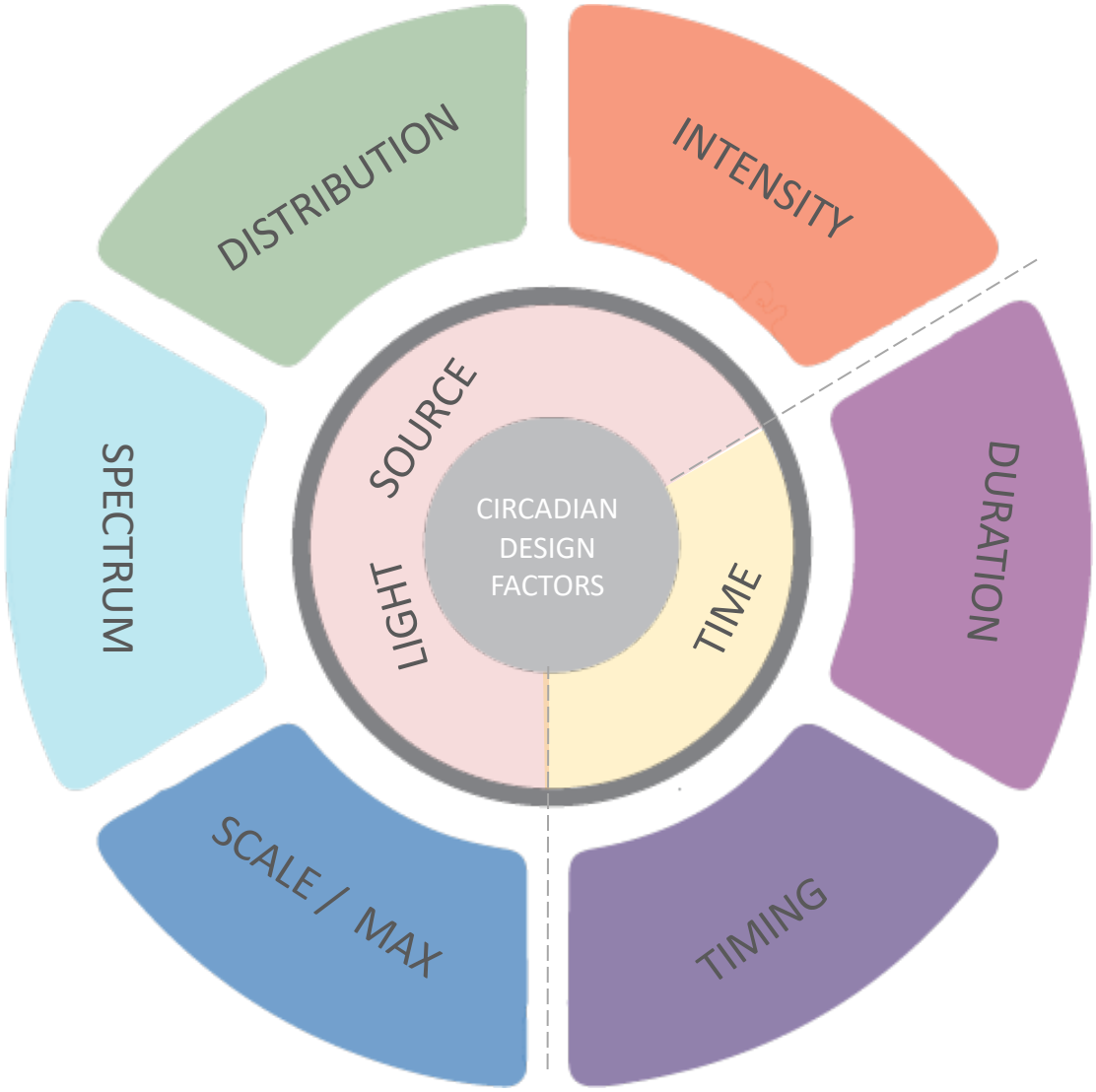
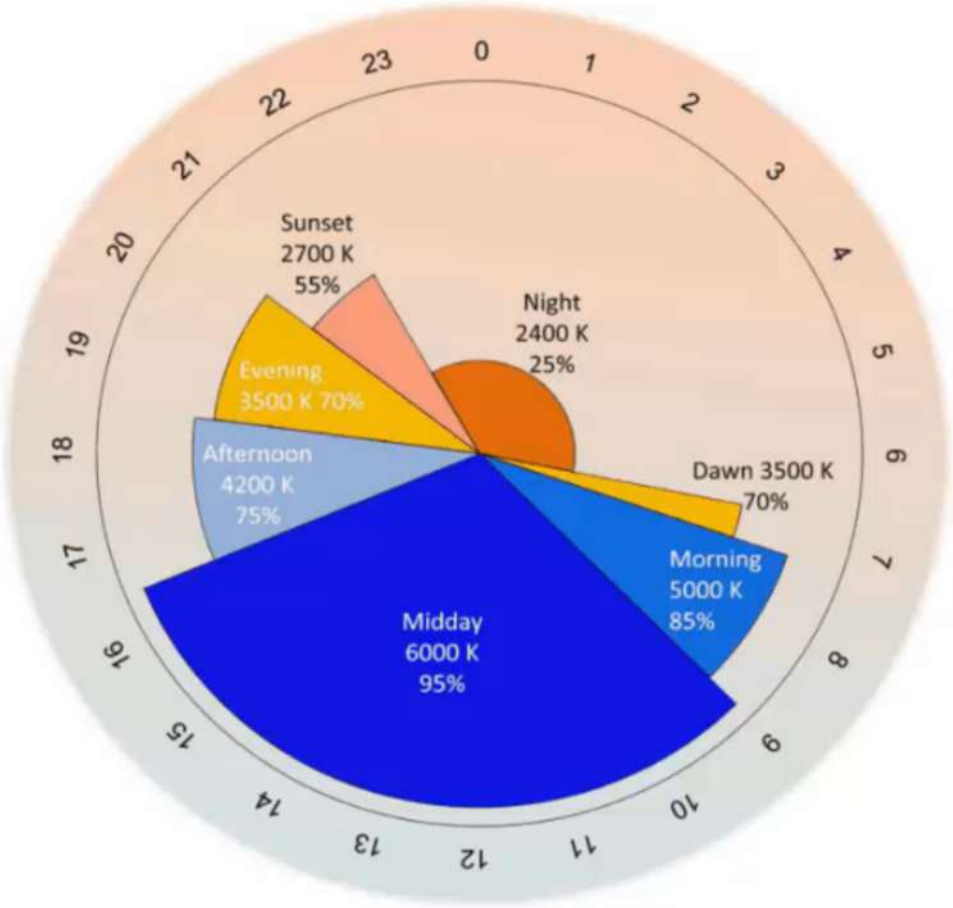
Circadian Design Factors

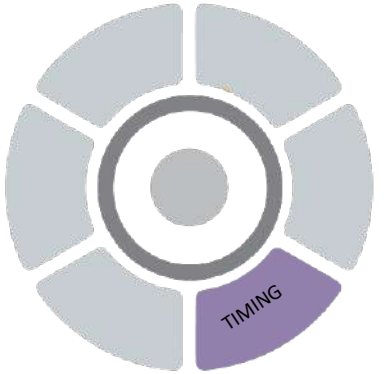
There are 6 environmental factors that have the most significant impact on human circadian rhythm.



Environmental Design Factors - Timing



Morning "dosing" of daylight has greater impact than exposure later in the day.

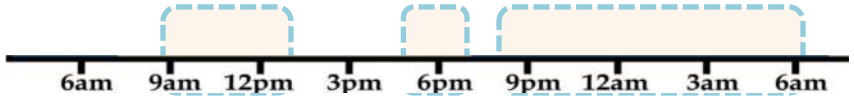


Morning Exposure is most effective

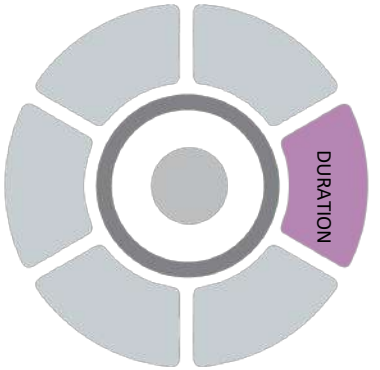
- 4 hours minimum between 9am – 1pm (Well 2.0)
- 2 hours minimum in morning or 7am-4pm (UL)

Evening Exposure is lowered

- Lower levels after 8pm (Well v2.0)
- Lower levels 5-7pm and less after 8pm (UL)

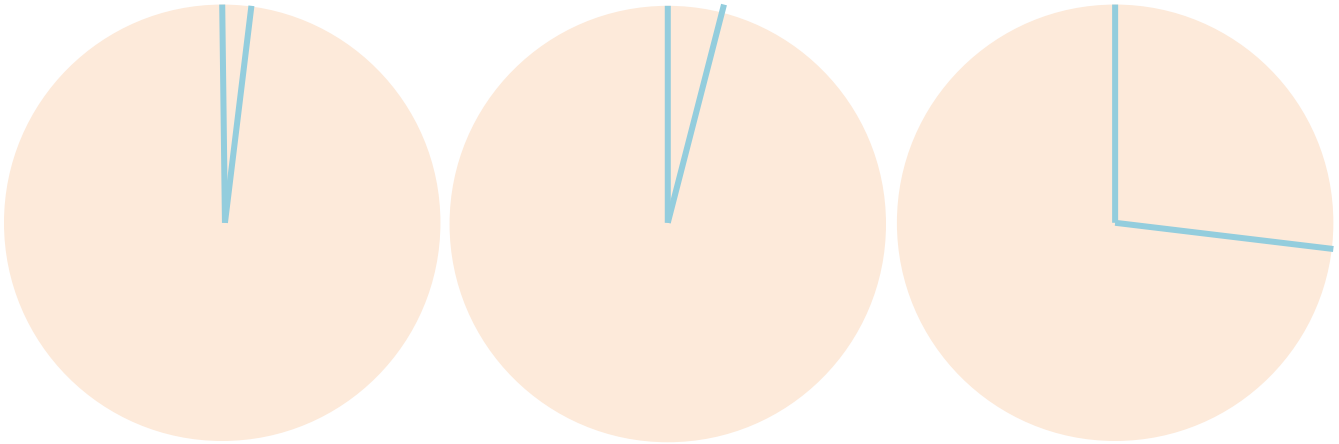


Environmental Design Factors – Duration (Exposure)



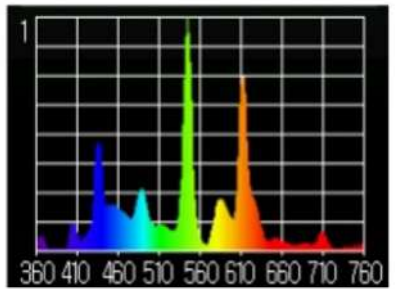
Length of exposure to light

- minimum 2 hours of daylight exposure each day
- lower intensity, longer duration of exposure can have same impact
- **Duration**, **spectrum** and **circadian function** are integrated considerations

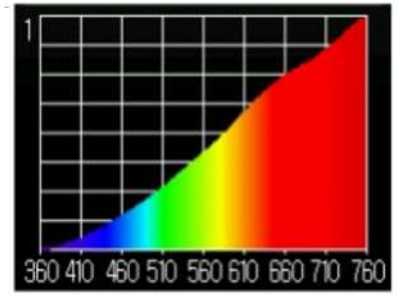


Environmental Design Factors - Spectrum

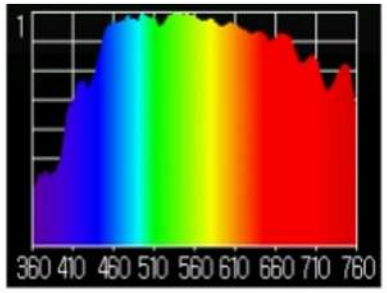
Our circadian receptors are more sensitive to blue wavelengths



Fluorescent



Incandescent



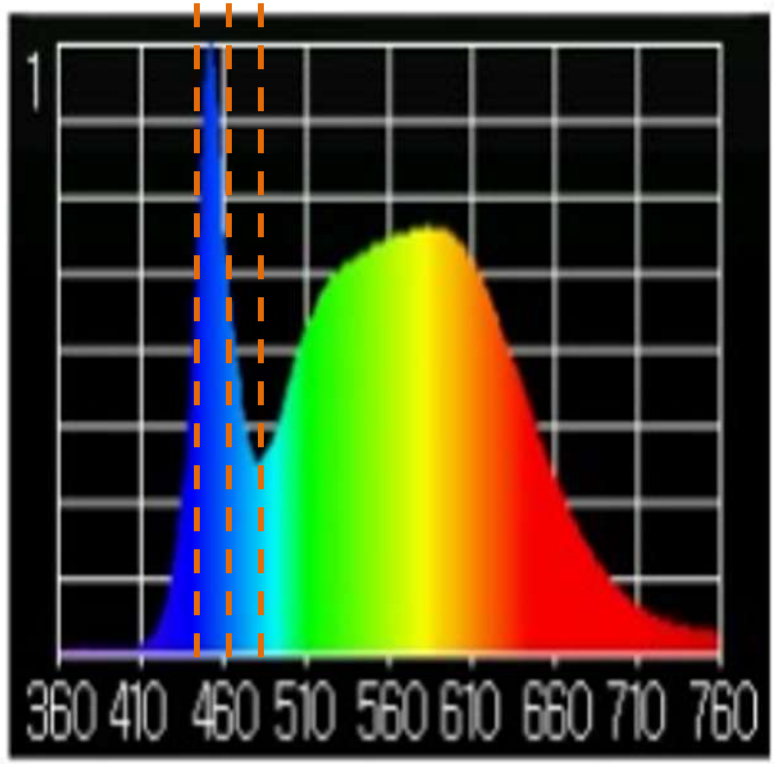
Daylight

Spectral Power Distribution

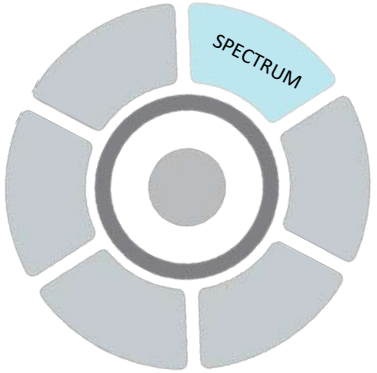
445nM phase shifting for 6.5 hour exposure

460nM phase shifting

480-490nM traditional focus



Phosphor Coated LED



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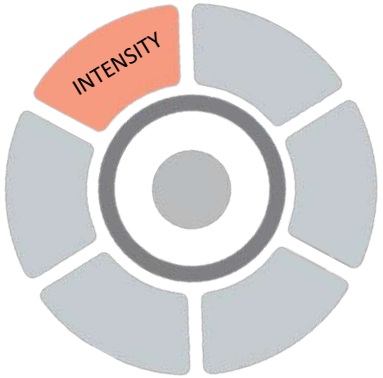
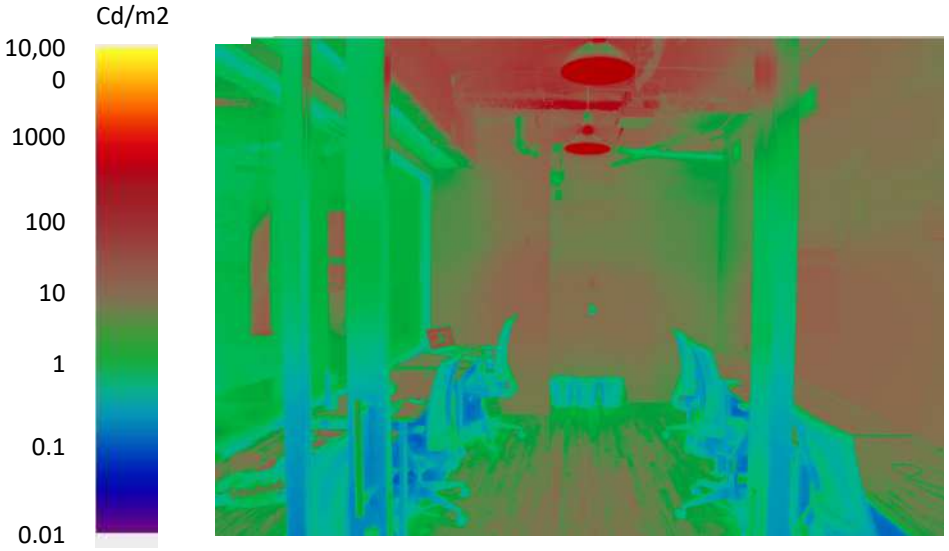


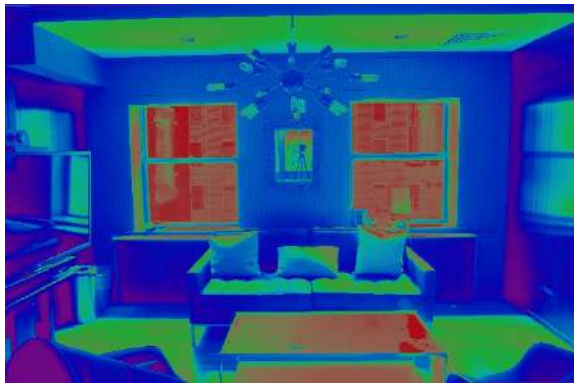
Magnitude of light exposure

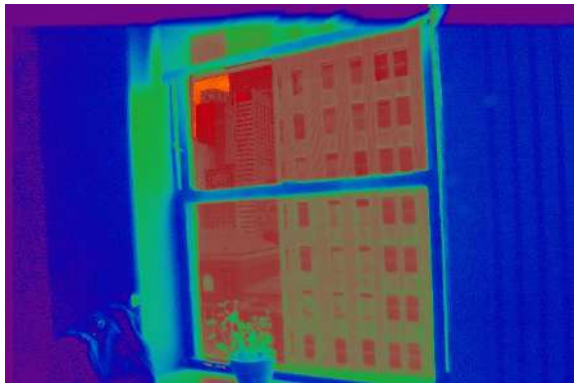
The interior built environment and electric light deliver significantly lower intensity light than daylight.

Consider strategies for program that may qualify as “regularly occupied spaces” for Well accreditation, e.g. offices, lounges.

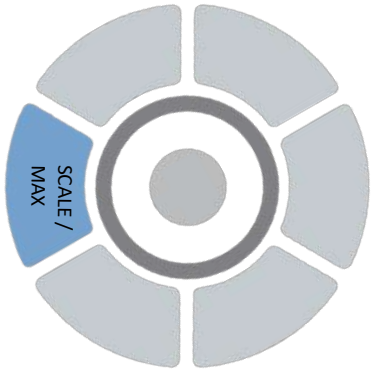
Patient and staff access to views and daylight can help, though nothing beats going outside!







Consider staff lounges, offices, conference room and patient rooms for daylight and electric light potential.

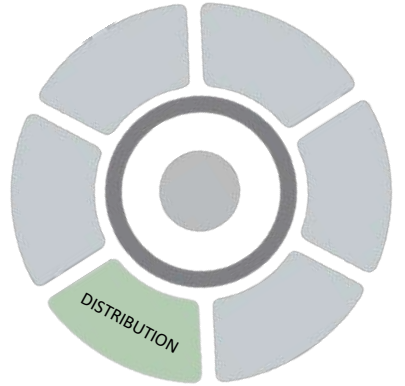


Light history

- **Sensitivity** is influenced by your typical extremes + range exposure to light
- The human circadian system **adapts to prior light exposure**

- Light exposure earlier in the day affects the biological potency of light later in the day
- Extended periods under dim light may negatively impact subsequent sleep
- There is considerable interindividual variability in the response to evening light

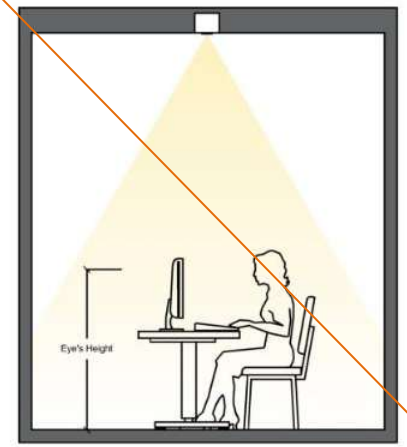
Environmental Design Factors - Distribution



Vertical Illuminance is key

Well V2.0 and UL 24480 refer to vertical illumination at eye

Task oriented horizontal lighting standards and targets are less relevant



Tendency for overhead lighting

30 - 45 Moderate

45 - 90 Optimal

< 90 Little Effect

Cluttered vertical surfaces

Strategies by Space Type

Spaces Impacted

Where is it most beneficial to implement circadian strategies?

Nurse's Stations & medical staff lounges

Residents' Facility / Long term care

Night Shift Workers

ICU / Patient Room

NICU

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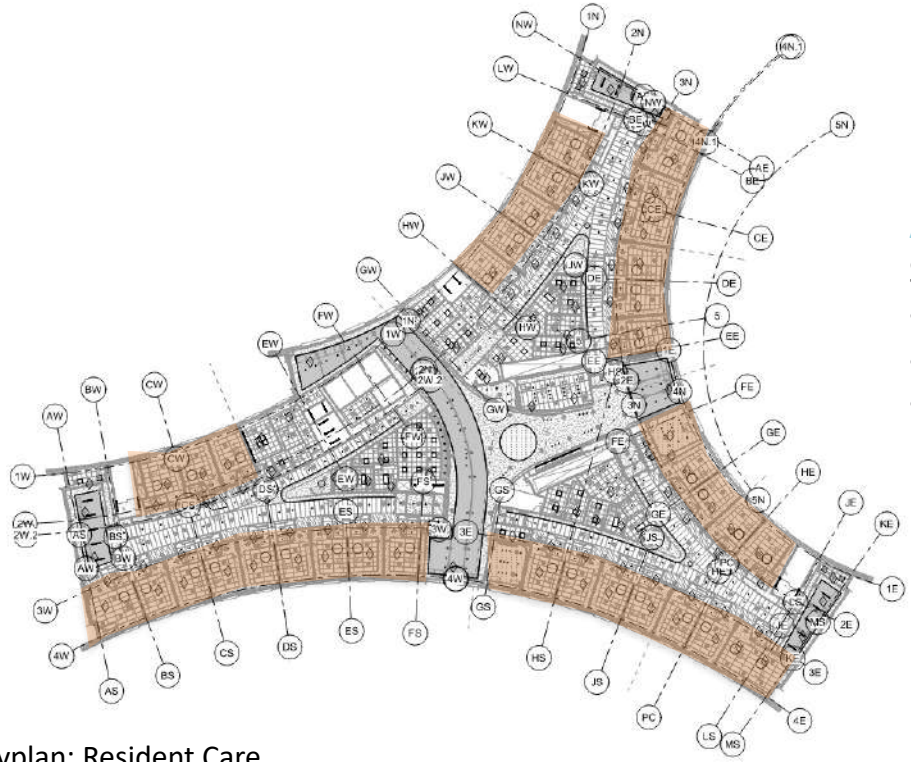
Strategies: Resident Care



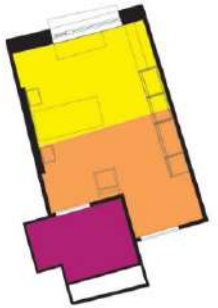
Keyplan: Resident Care

Architectural Moves

Support Daylight Harvest:

- Fenestration
- Orientation
- Material Finishes

Daylight Autonomy



Daylight Zone 1

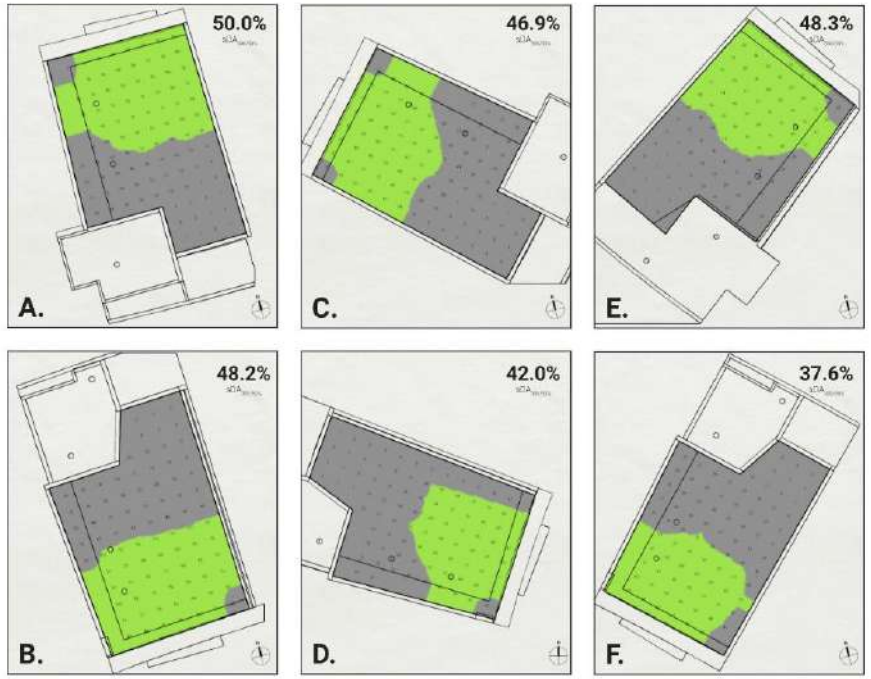
This is the primary daylight zone that can be sufficiently lit during daylight hours without potential need for electric lighting support. A photocell can determine when electric lighting is required to supplement the daylight resources in this area.

Daylight Zone 2

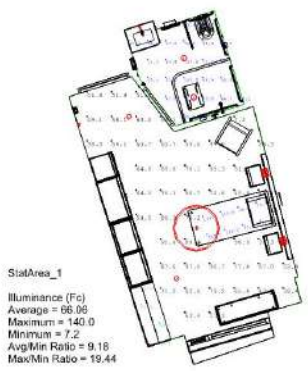
Requires electric lighting to provide sufficient illuminance for residents to be comfortable and complete tasks. A photocell will determine when electric lighting is required to supplement the daylight resources in this area.

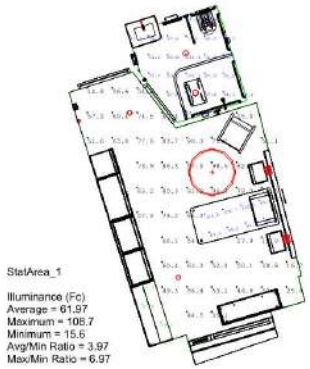
Daylight Zone 3

Requires electric light in all conditions as there is insuffient access to daylight to meet required levels of illumination at any time of day or year.

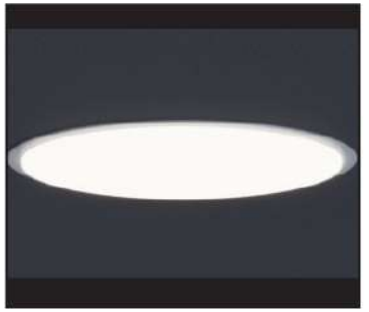


Strategies: Resident Care



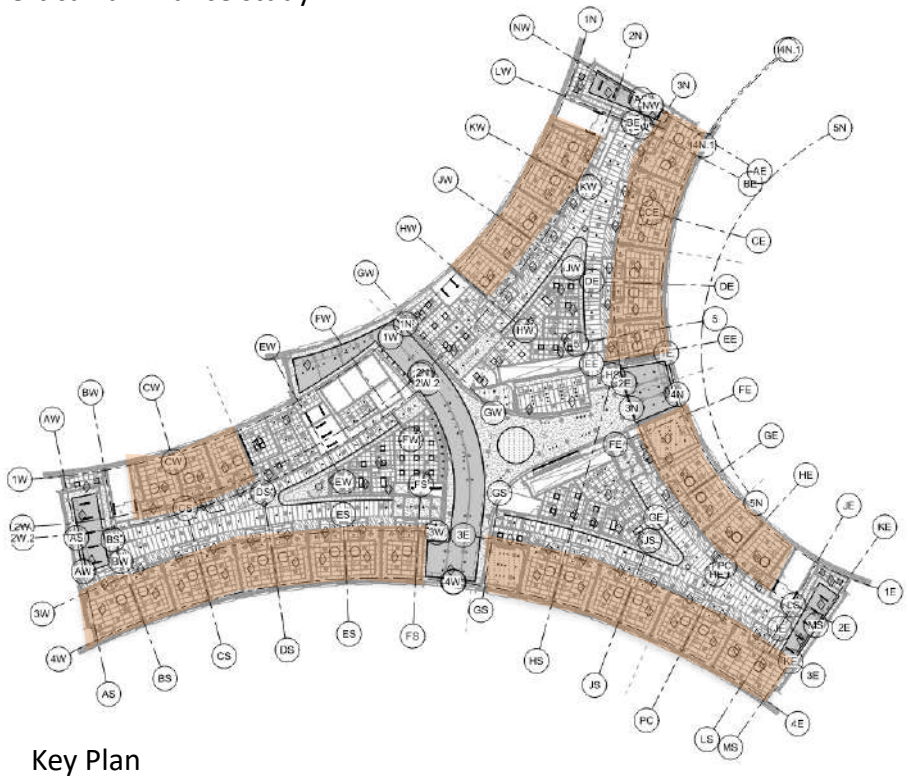


Vertical luminance study



Tunable Dome fixture

Wall Sconce



Key Plan

Typical Resident Care Lighting Layout

Strategies: ICU (Intensive Care Unit) / Patient Rooms

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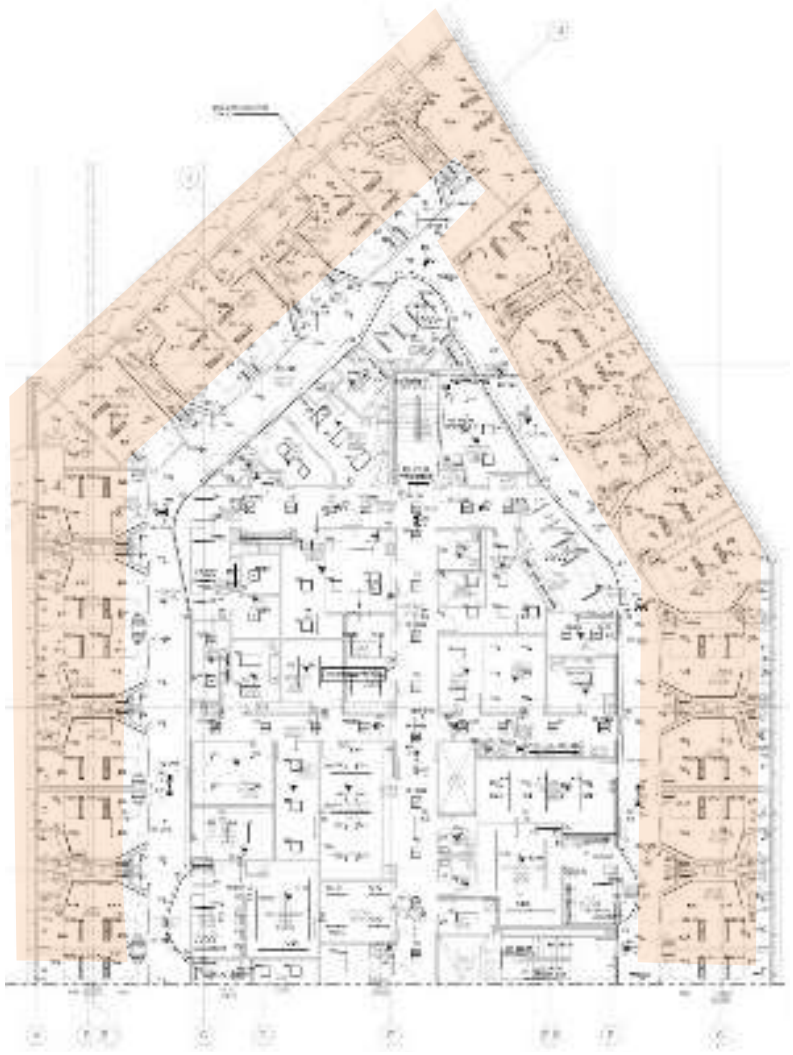
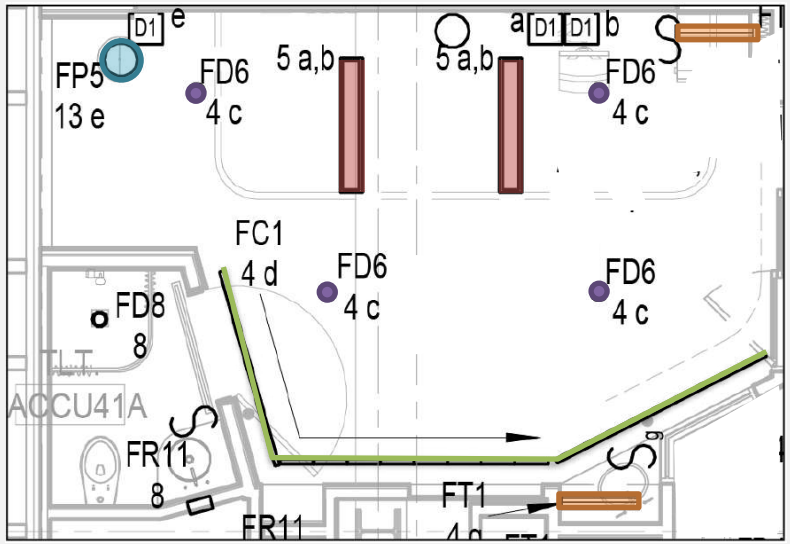
Strategies: ICU (Intensive Care Unit) / Patient Rooms

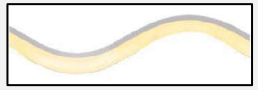


Keyplan: ICU Rooms



Typical ICU Room Lighting Layout

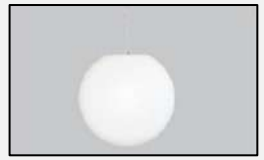
Exam/ Ambient



Cove

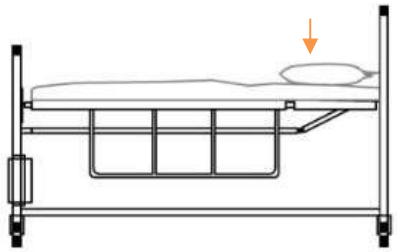
Task Light

Downlight

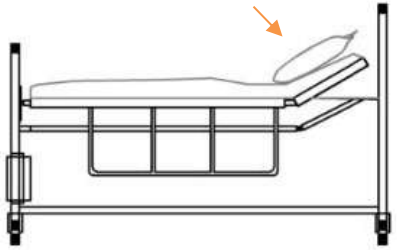


Pendant

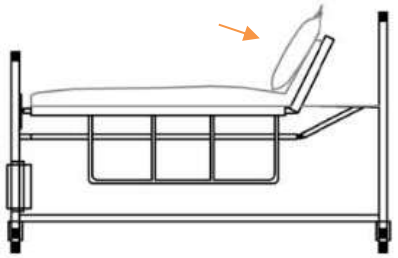
Strategies: ICU (Intensive Care Unit) / Patient Rooms



Flat position

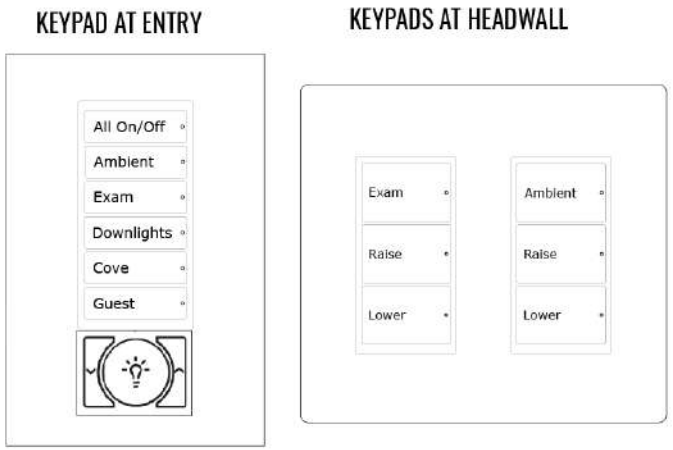


45 degrees position



70 degrees position

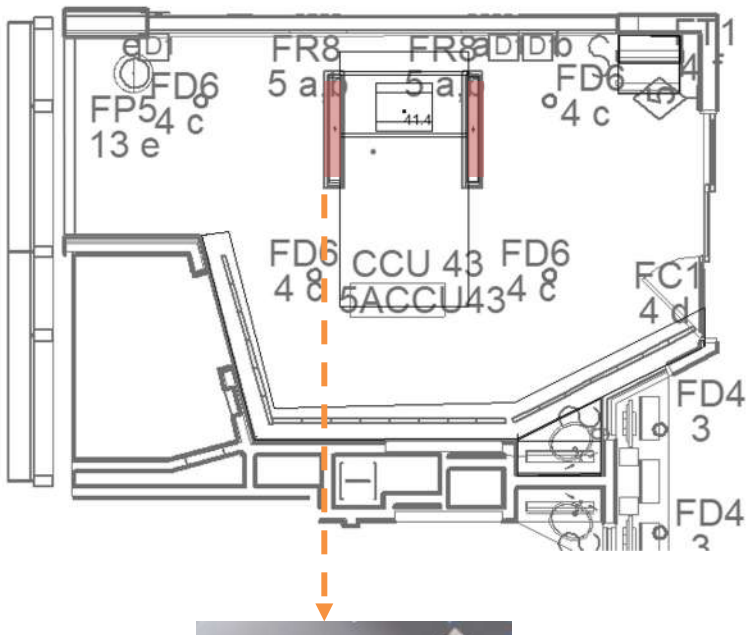
Lighting Scenes and adjustments



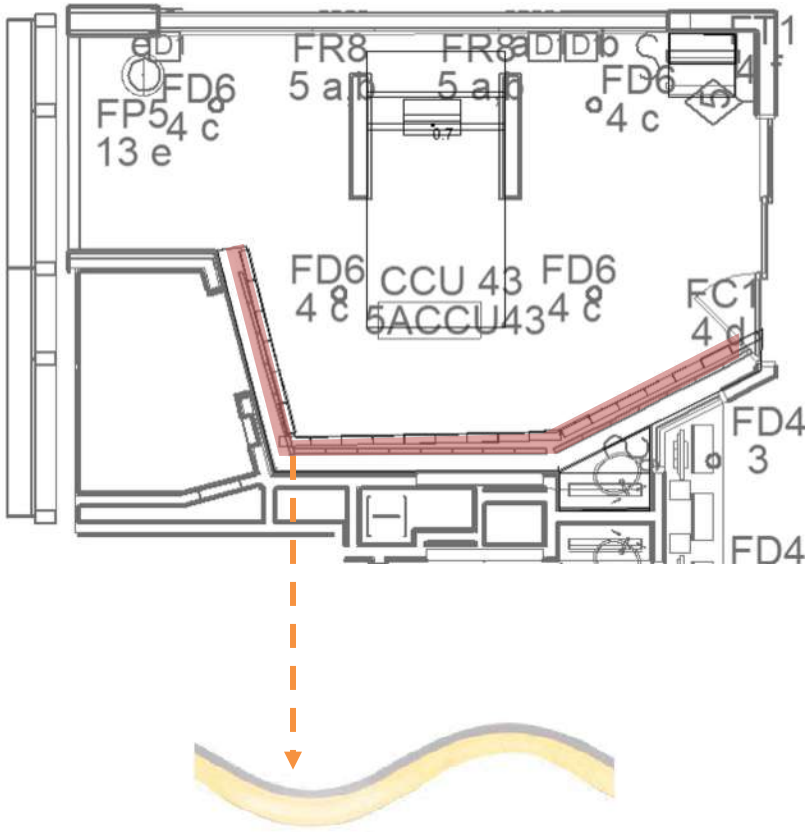
Control Description - ICU Rooms

(2) Local programmable wall station, located at door to room and at head of bed. These controls would have a timer with “locked” presets to achieve the CS during the day.

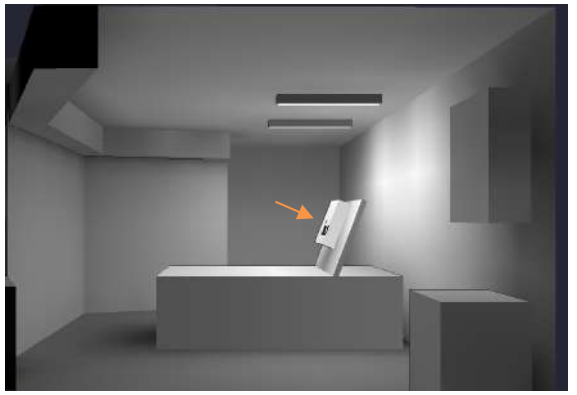
Strategies: ICU (Intensive Care Unit) / Patient Rooms

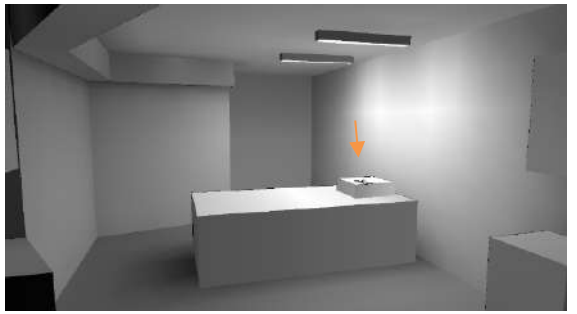


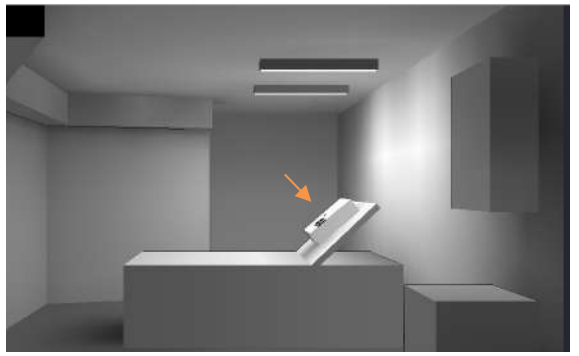
Result with Ambient fixture:
41.4 FC = 445 lux



Result with Cove fixture:
0.7 FC = 7.5 lux







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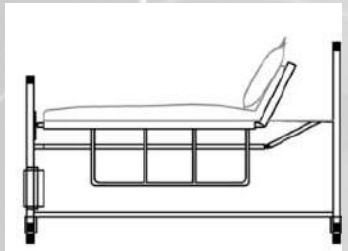
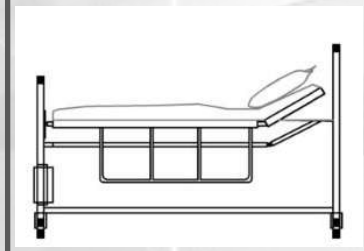
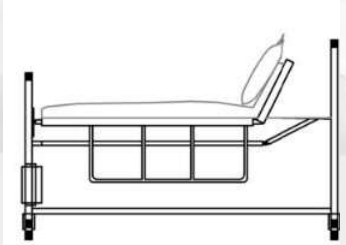
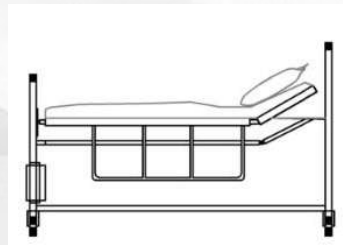
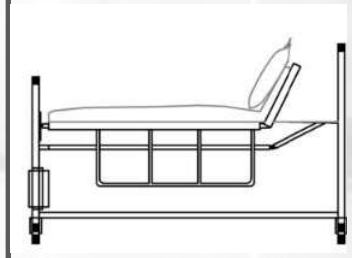
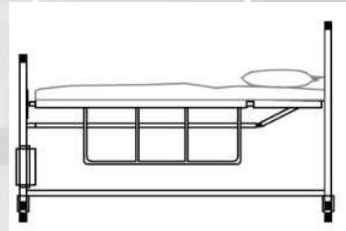
Patient room: Circadian Stimulus needed during the day

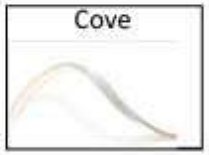
MELATONIN

Eating position	Reclined position	Eating position	Reclined position	Eating position	Resting position
					
7am – 9am	9am – 12pm	12pm – 2pm	2pm – 4pm	4pm – 8pm	8pm – 7am
CIRCADIAN STIMULUS 0.3	0.25	0.3	0.25	0.2	0.1

CORTISOL

0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

Circadian Stimulus calculation: Results

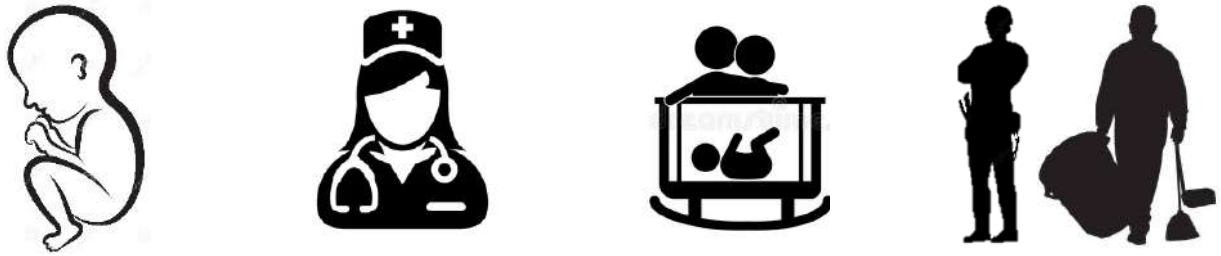
	7AM-9AM	9AM-12PM	12PM-2PM	2PM-4PM	4PM-8PM	8PM-7AM
Ambient linear 	Min. output to 65%	Min. output to 50%	100%	Min. output to 50%	Min. output to 30%	Max. output to 25%
Exam Linear 	On when needed	On when needed	On when needed	On when needed	On when needed	On when needed
Cove 	100%	Min. output to 50%	Min. output to 50%	Min. output to 50%	Min. output to 40%	100%
Downlights 	On when needed	On when needed	On when needed	On when needed	On when needed	On when needed
CIRCADIAN STIMULUS	0.3	0.25	0.3	0.25	0.2	0.1

Strategies: NICU (Neonatal Intensive Care Unit)





Users



Newborn | Health Staff | Parents / Guest | Maintenance

IESNA Lighting Handbook: Reference and Application. 9th. New York, NY

Standard 14: Ambient lighting in Infant Care Area: 10 to 600 lux with adjustable, manual controls

Standard 15: Procedure lighting in Infant Care Area: 2000 lux for critical areas while protecting the infant's developing retinae

Standard 16: Illumination of Support Areas : 300 lux

Standard 17: Daylighting : Access to daylight, with controls to limit direct sunlight

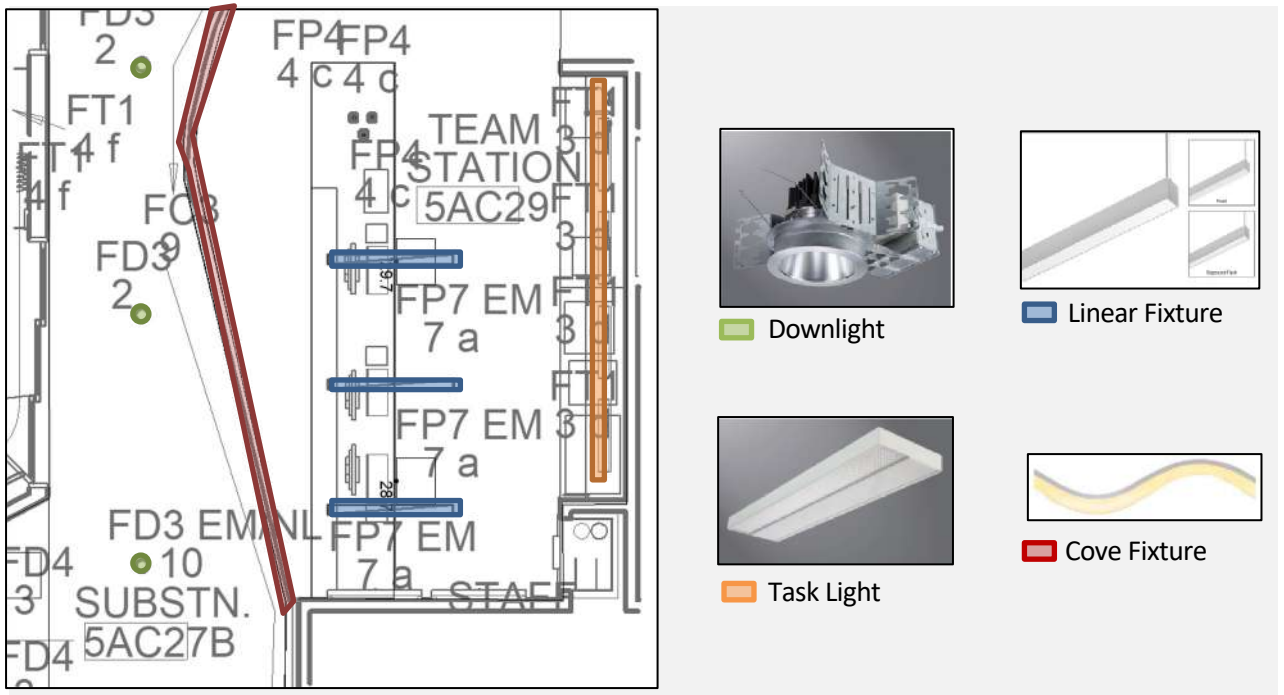
1. Rizzo P, Rea M, White R. Lighting for Today's Neonatal Intensive Care Unit. Newborn and Infant Nursing Reviews. 2010;10(2):107–113

Strategies: Nurse Stations

leducation.org

Strategies: Nurse Stations Lighting Plan

Key plan: Nurse Stations



Typical Nurse Station Lighting Layout

Strategies: Night Shift Work / Finishes & RGB fixtures

Night Shift Workers

Shift work is associated with increased risks of developing cancer and other diseases due to light at night that suppress melatonin.

Recommendations

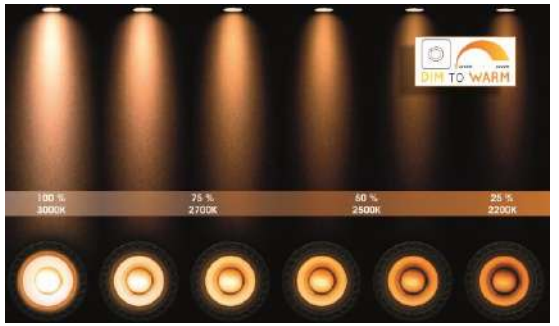
Studies show that red light increases alertness and performance at night, without suppressing melatonin and without disrupting circadian rhythms (similar effect to a cup of coffee).

leducation.org

Strategies: Night Shift Work / Dim to Warm technology

Comparative Study of Static vs Dim to Warm lighting

Task lighting adjusted to investigate static white vs. dim to warm to see Circadian Stimulus and EML variations.



Static White

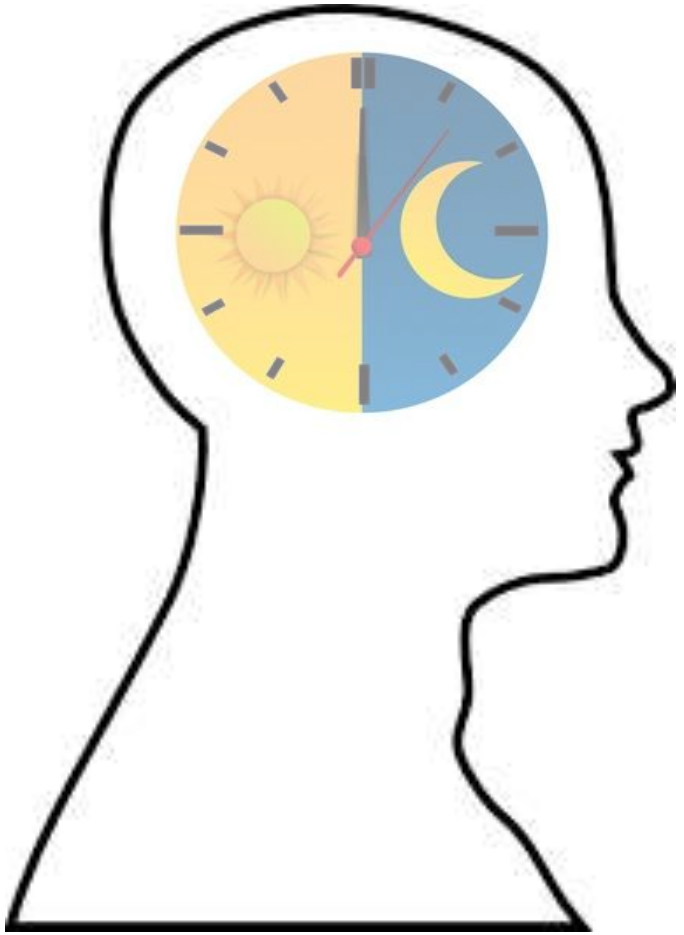
	7AM-4PM	4PM-8PM	8PM-7AM
Linear Pendant	Min. output to 50%	Min. output to 50%	Max. output to 35%
Cove lights	100%	100%	Max. output to 40%
Task light	100%	100%	Max. output to 40%
Downlight	100%	Min. Output to 50%	Max. output to 50%
CIRCADIAN STIMULUS	0.3	0.2	0.1
EML	131	192	54

Dim to Warm on task lights

	7AM-4PM	4PM-8PM	8PM-7AM
Linear Pendant	Min. output to 50%	Min. output to 50%	Max. output to 50%
Cove lights	100%	100%	Max. output to 50%
Task light	100%	100%	Max. output to 40%
Downlight	100%	Min. Output to 50%	Max. output to 50%
CIRCADIAN STIMULUS	0.3	0.2	0.1
EML	131	192	66

RECOMMENDATIONS

- High CS during the day, esp in the morning (>0.3) . Promotes alertness. A simple thing you can do is go for a morning walk for an hour after daybreak.
- Low CS in the evening (<0.1) to promote entrainment.
- Deliver red light with low CS in the even & overnight when you need to be alert – think shift work, esp. health care.
- Tunable lighting does not = circadian lighting
- Research is showing that light levels are more influential than color tuning

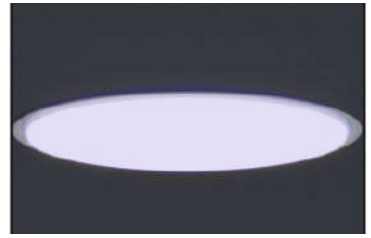


leducation.org

RECOMMENDATIONS

- Light at the eye is critical.
- Overhead lighting is about ½ less effective in CS
- Light vertical surfaces
- Light panel or light fixture at eye level
- Work facing a window
- Spectrum matters.
- CCT is not an indicator of CS

Lighting Strategies – Budget Analysis

	STATIC WHITE	DYNAMIC WHITE	BIO-CENTRIC + DYNAMIC WHITE
			
FIXTURE COST ($)	x	x + 40%	x + 50%
CONTROLS ($)	x	x + 40%	x + 50%

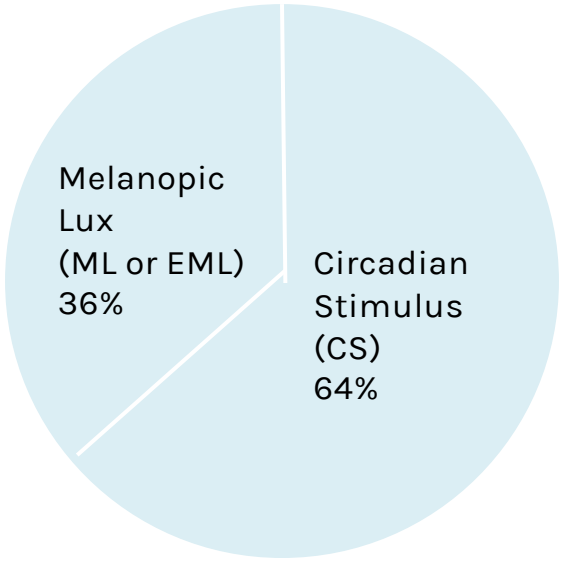
Performing Circadian Calculations

Circadian Metrics Debate

Equivalent Melanopic Lux (EML) V **Circadian Stimulus (CS)**

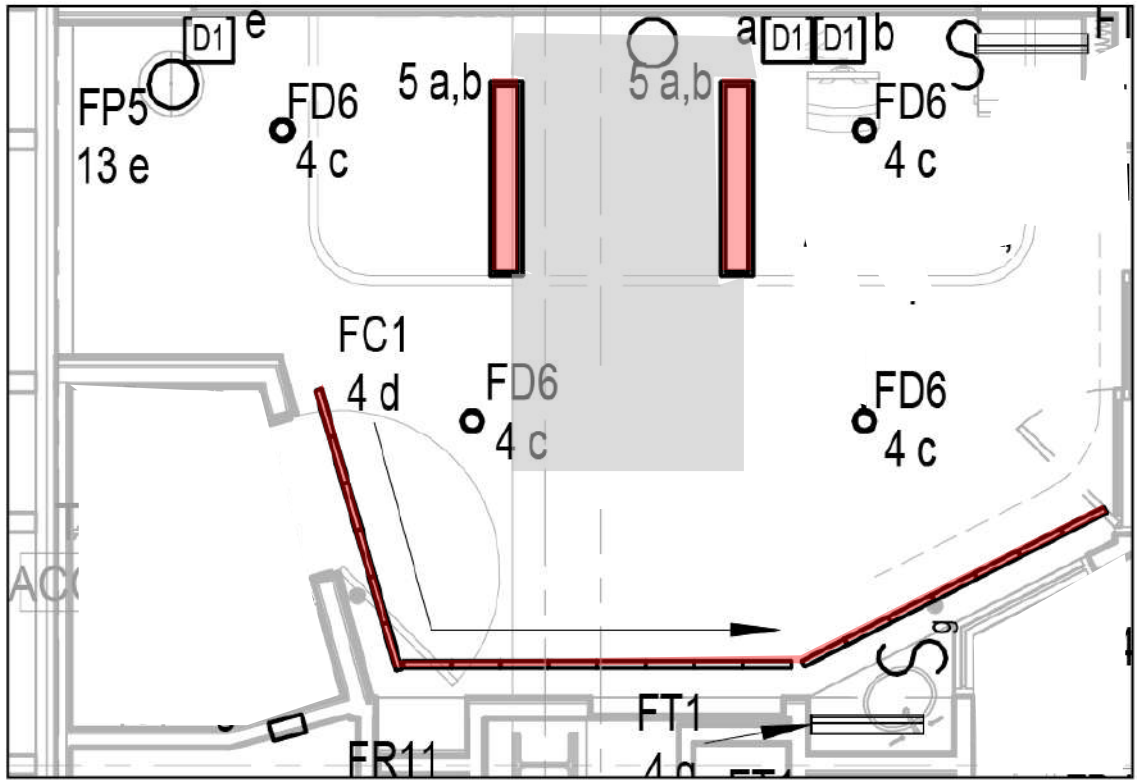
LD&A industry 2018 survey

"Which circadian metric do you use?"



Lesniak, Natalia and Ed Clark, "Putting it Into Practice: Circadian Survey." LD+A Oct 2018, p44-48

Studying the room lighting layout

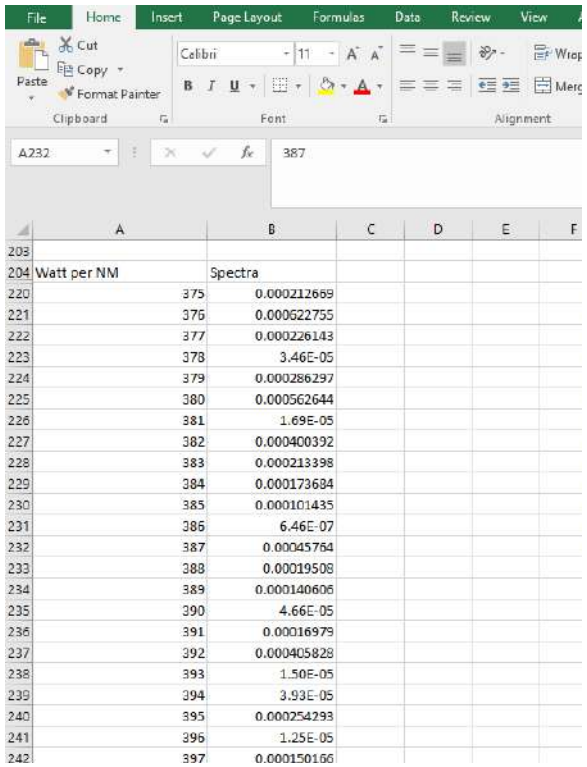


Exam and Ambient fixture

Cove/ linear fixture

Actions to take care prior starting a CS or EML study:

1-Select fixture: Optics and CCT.
2-Select Manufacturer
3-Ask to the Manufacturer to provide “Spectral Power distribution” (SPD)
4- Start Light level calculations (could be on AGI-32)



	A	B
203		
204	Watt per NM	Spectra
220	375	0.000212669
221	376	0.000622755
222	377	0.000226143
223	378	3.46E-05
224	379	0.000286297
225	380	0.000562644
226	381	1.69E-05
227	382	0.000400392
228	383	0.000213398
229	384	0.000173684
230	385	0.000101435
231	386	6.46E-07
232	387	0.00045764
233	388	0.00019508
234	389	0.000140606
235	390	4.66E-05
236	391	0.00016979
237	392	0.000405828
238	393	1.50E-05
239	394	3.93E-05
240	395	0.000254293
241	396	1.25E-05
242	397	0.000150166

Example of the file you will receive with the SPD information

leducation.org

Circadian Stimulus calculation: Website

https://www.lrc.rpi.edu/cscalculator/

Lighting Research Center | Light and Health | Circadian-Effective Light | Designing with Circadian Stimulus | Contact | Instructional Video | Help off

Step 1: Select Sources

Select Available Sources

Manufacturer: Any

CCT: Any

Lamp: Any

Keyword: Search Sources

Reset Filters

Add Custom Source

Available Sources

- CIE A: Standard Incandescent
- CIE D50: Horizon Daylight
- CIE D55: Mid-Morning Daylight
- CIE D65: Average Daylight
- CIE D75: Overcast Daylight
- CIE E: Equal Energy
- CIE F1: Daylight Fluorescent
- CIE F2: Cool White Fluorescent
- CIE F3: White Fluorescent
- CIE F4: Warm White Fluorescent
- CIE F5: Daylight Fluorescent

Step 2: Edit Variables

Additional Variables

Biological Input Variables	Value
Macular Pigment Optical Density:	0.5

Source Illuminances

Enter a vertical illuminance value in lux to determine a CS value based on your chosen SPD.

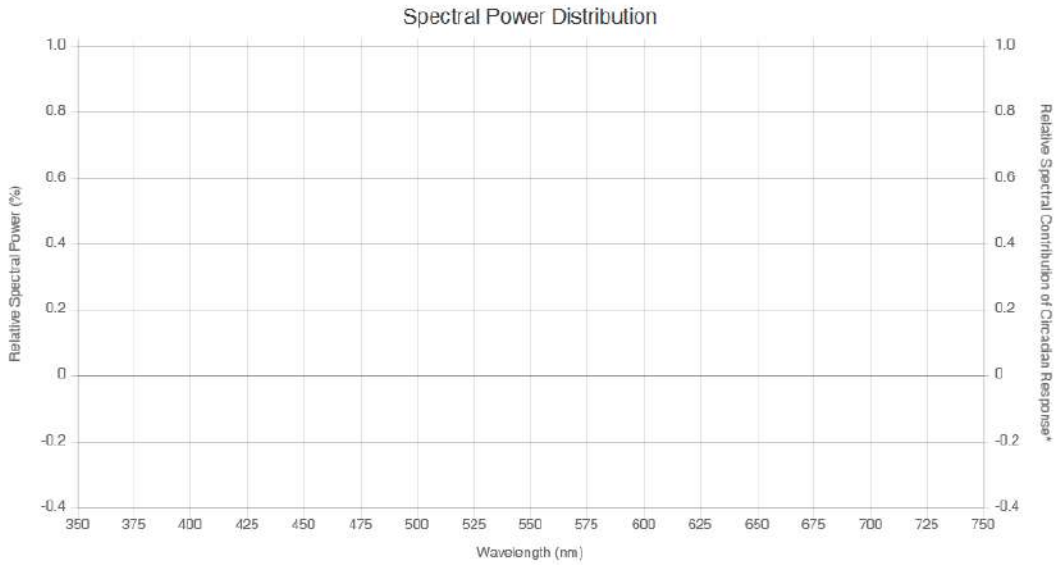
Source	Vertical Photopic Illuminance (lx)	Remove Source

No Sources Selected

Step 3: View Results

Output Plots

Spectral Power Distribution | Chromaticity | Color Rendering Metrics

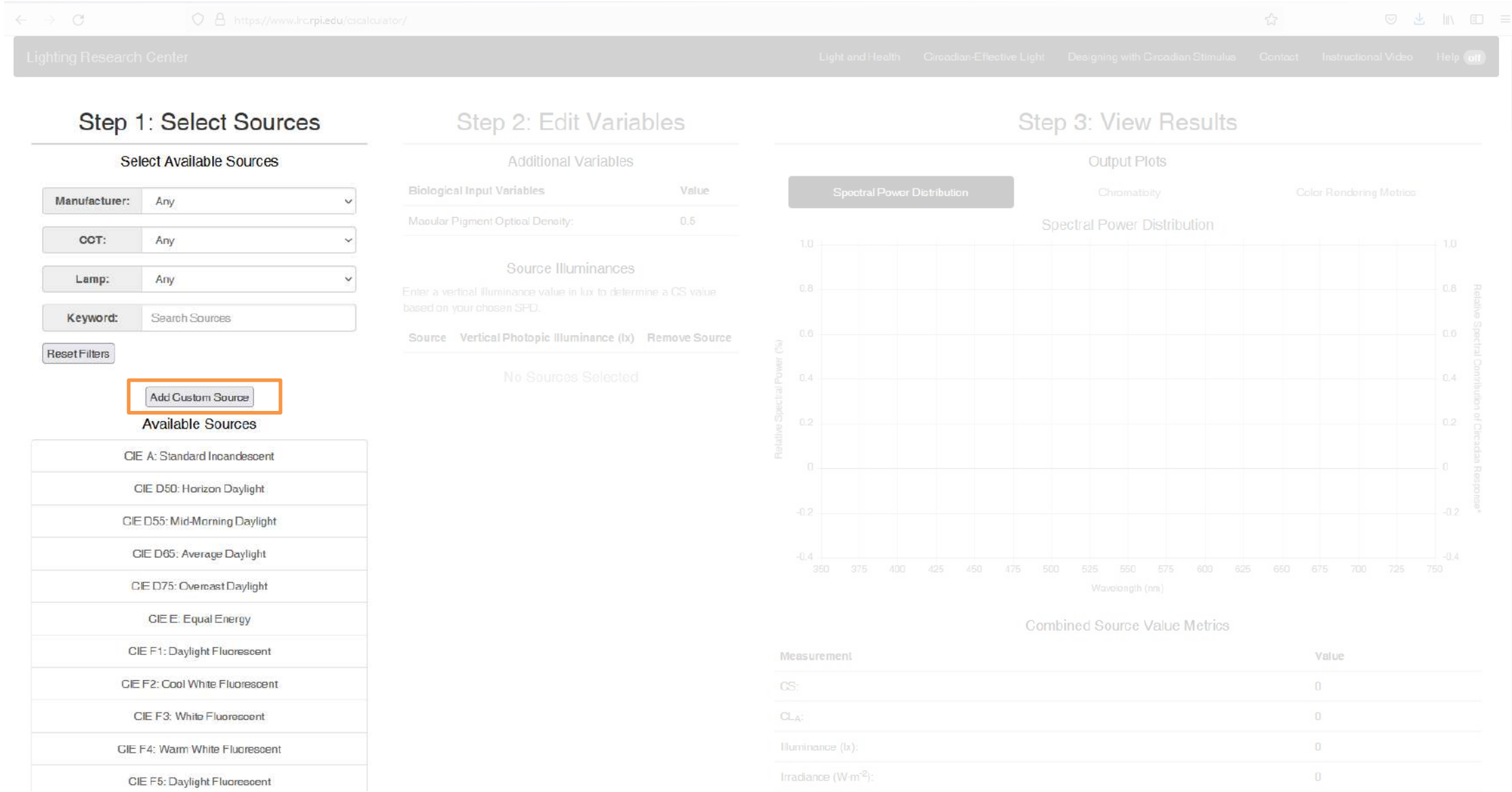


Combined Source Value Metrics

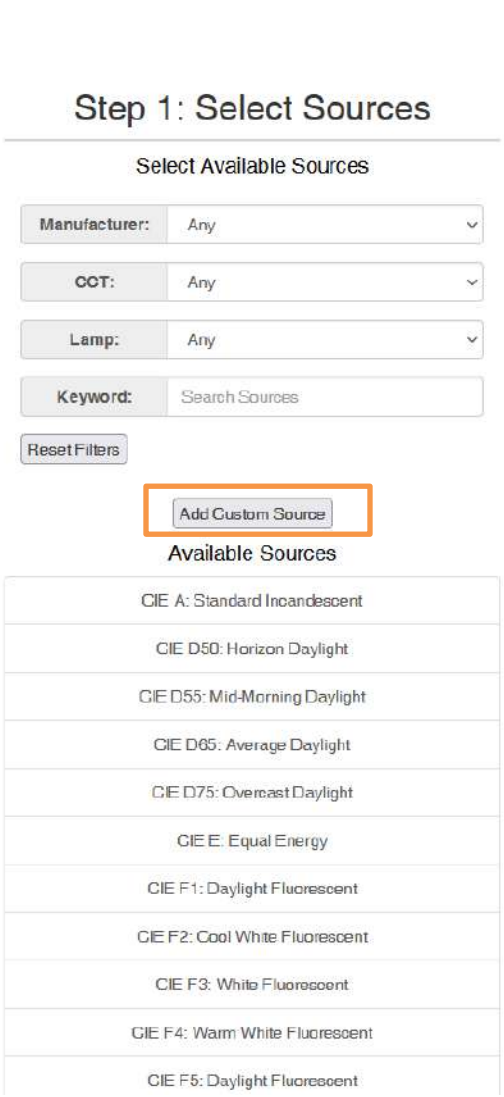
Measurement	Value
CS:	0
CL_A:	0
Illuminance (lx):	0
Irradiance ($W \cdot m^{-2}$):	0

leducation.org

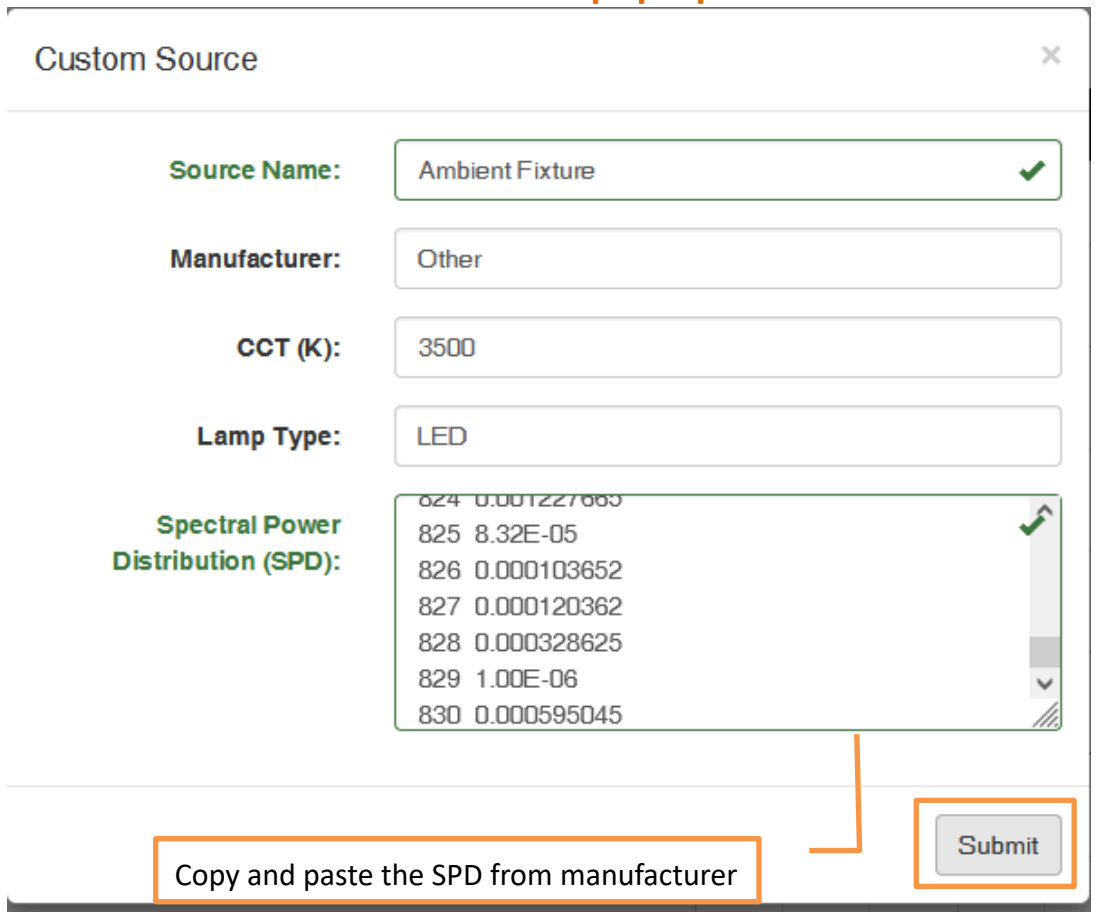
Circadian Stimulus calculation: Walkthrough



Circadian Stimulus calculation: Walkthrough



This window will pop-up



Copy and paste the SPD from manufacturer

This will be your lighting fixture

leducation.org

Circadian Stimulus calculation: Walkthrough

Step 1: Select Sources

Select Available Sources

Manufacturer: Any

CCT: Any

Lamp: Any

Keyword: Search Sources

Reset Filters

Add Custom Source

Available Sources

LED Hybrid Blue Pump 1

LED Phosphor Blue Pump 16

LED Phosphor Blue Pump 23

LED Phosphor Blue Pump 24

LED Phosphor Blue Pump 26

LED Phosphor Blue Pump 31

LED Phosphor Blue Pump 44

LED Phosphor Blue Pump 46

LED Phosphor Blue Pump 47

LED Phosphor Blue Pump 48

LED Phosphor Blue Pump 53

LED Phosphor Blue Pump 54

LED Phosphor Blue Pump 65

LED Phosphor Blue Pump 73

LED Phosphor Blue Pump 79

Step 2: Edit Variables

Additional Variables

Biological Input Variables	Value
Macular Pigment Optical Density:	0.5

Source Illuminances

Enter a vertical illuminance value in lux to determine a CS value based on your chosen SPD.

Source	Vertical Photopic Illuminance (lx)	Remove Source
Ambient Fixture	0	
Cove	0	

We place the results of the calculations (Lux) here

Reminder: Each lighting fixture needs a separate calculation

Step 3: View Results

Output Plots

Spectral Power Distribution | Chromaticity | Color Rendering Metrics

* For the Specified Spectral Power Distribution [Spectrum, Amount]

Information on the calculation of Circadian Light, Corrigendum

Combined Source Value Metrics

Measurement	Value
CS:	0.000
CL_A:	0.00
Illuminance (lx):	0

leducation.org

Circadian Stimulus calculation: Walkthrough

Step 1: Select Sources

Select Available Sources

Manufacturer: Any

CCT: Any

Lamp: Any

Keyword: Search Sources

Reset Filters

Add Custom Source

Available Sources

LED Hybrid Blue Pump 1
LED Phosphor Blue Pump 16
LED Phosphor Blue Pump 23
LED Phosphor Blue Pump 24
LED Phosphor Blue Pump 26
LED Phosphor Blue Pump 31
LED Phosphor Blue Pump 44
LED Phosphor Blue Pump 46
LED Phosphor Blue Pump 47
LED Phosphor Blue Pump 48
LED Phosphor Blue Pump 53
LED Phosphor Blue Pump 54
LED Phosphor Blue Pump 65
LED Phosphor Blue Pump 73
LED Phosphor Blue Pump 79

Step 2: Edit Variables

Additional Variables

Biological Input Variables	Value
Macular Pigment Optical Density	0.5

Source Illuminances

Enter a vertical illuminance value in lux to determine a CS value based on your chosen SPD.

Source	Vertical Photopic Illuminance (lx)	Remove Source
Cove Fixture	80	
Patient Ambient fixture	550	

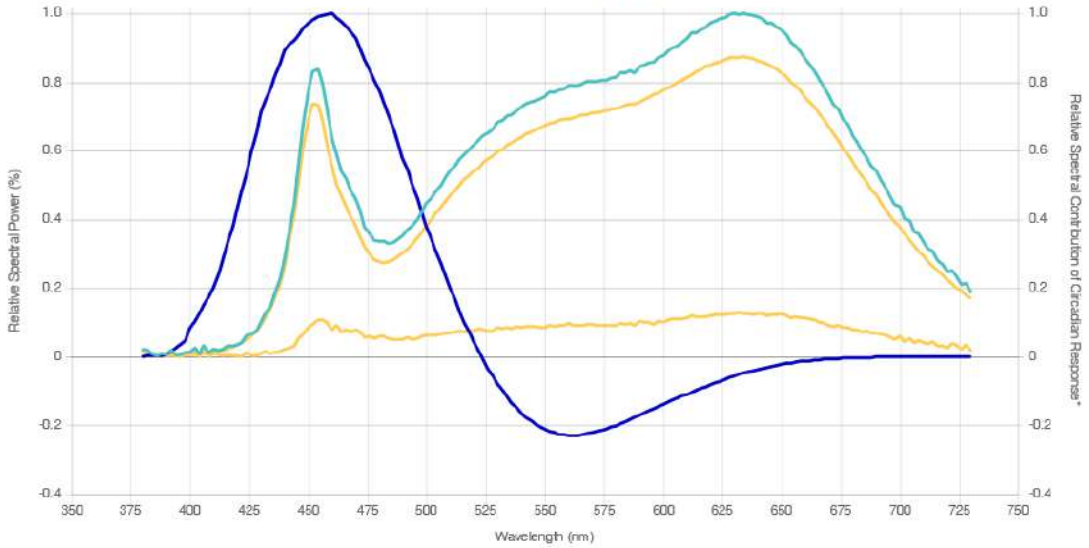
Here is using full intensity, we are getting over the desired CS levels.

Step 3: View Results

Output Plots

Spectral Power Distribution | Chromaticity | Color Rendering Metrics

Spectral Power Distribution



Legend

- Combined Source SPD
- Relative Spectral Contribution of the Circadian Response*: Cool
- Cove Fixture
- Patient Ambient fixture

* For the Specified Spectral Power Distribution [Spectrum, Amount]

Information on the calculation of Circadian Light, Corrigendum

Combined Source Value Metrics

Measurement	Value
CS:	0.342
CL_A:	340.91
Illuminance (lx):	630

leducation.org

Circadian Stimulus calculation: Walkthrough

Step 1: Select Sources

Select Available Sources

Manufacturer: Any

CCT: Any

Lamp: Any

Keyword: Search Sources

Reset Filters

Add Custom Source

Available Sources

LED Hybrid Blue Pump 1

LED Phosphor Blue Pump 16

LED Phosphor Blue Pump 23

LED Phosphor Blue Pump 24

LED Phosphor Blue Pump 26

LED Phosphor Blue Pump 31

LED Phosphor Blue Pump 44

LED Phosphor Blue Pump 46

LED Phosphor Blue Pump 47

LED Phosphor Blue Pump 48

LED Phosphor Blue Pump 53

LED Phosphor Blue Pump 54

LED Phosphor Blue Pump 66

LED Phosphor Blue Pump 73

LED Phosphor Blue Pump 79

LED Phosphor Blue Pump 82

Step 2: Edit Variables

Additional Variables

Biological Input Variables	Value
Macular Pigment Optical Density:	0.5

Source Illuminances

Enter a vertical illuminance value in lux to determine a CS value based on your chosen SPD.

Source	Vertical Photopic Illuminance (lx)	Remove Source
Cove Fixture	60	
Patient Ambient fixture	450	

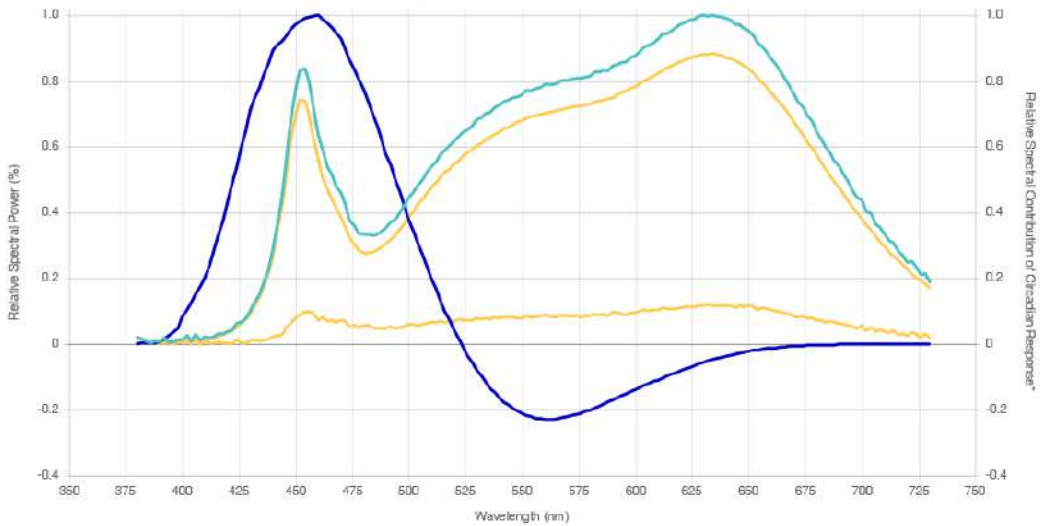
We adjusted the lighting levels and now we are getting the desired CS Level.

Step 3: View Results

Output Plots

Spectral Power Distribution | Chromaticity | Color Rendering Metrics

Spectral Power Distribution



Legend

- Combined Source SPD
- Relative Spectral Contribution of the Circadian Response*: Cool
- Cove Fixture
- Patient Ambient fixture

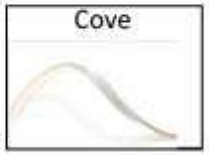
* For the Specified Spectral Power Distribution [Spectrum, Amount]

Information on the calculation of Circadian Light, Corrigendum

Combined Source Value Metrics

Measurement	Value
CS:	0.299
CL_A:	272.30
Illuminance (lx):	510

Circadian Stimulus calculation: Results

	7AM-9AM	9AM-12PM	12PM-2PM	2PM-4PM	4PM-8PM	8PM-7AM
Ambient linear 	Min. output to 65%	Min. output to 50%	100%	Min. output to 50%	Min. output to 30%	Max. output to 25%
Exam Linear 	On when needed	On when needed	On when needed	On when needed	On when needed	On when needed
Cove 	100%	Min. output to 50%	Min. output to 50%	Min. output to 50%	Min. output to 40%	100%
Downlights 	On when needed	On when needed	On when needed	On when needed	On when needed	On when needed
CIRCADIAN STIMULUS	0.3	0.25	0.3	0.25	0.2	0.1

Nurse Station Example for Equivalent Melanopic Lux (EML)

leducation.org

Equivalent Melanopic Lux (EML) Calculation: Walkthrough

Sample LED 2700 K

λ (nm)	Lamp data	circadian	visual	lamp*c	lamp*v
380	0.000	0.0009	0.0000	0.0000	0
385	0.000	0.0017	0.0001	0.0000	0
390	0.000	0.0031	0.0001	0.0000	0
395	0.000	0.0059	0.0002	0.0000	0
400	0.000	0.0114	0.0004	0.0000	0
405	0.000	0.0228	0.0006	0.0000	0
410	0.001	0.0462	0.0012	0.0001	1.546E-06
415	0.002	0.0795	0.0022	0.0002	4.864E-06
420	0.004	0.1372	0.0040	0.0005	1.515E-05
425	0.007	0.1871	0.0073	0.0013	4.941E-05
430	0.011	0.2539	0.0116	0.0029	0.000132
435	0.017	0.3207	0.0168	0.0054	0.0002839
440	0.023	0.4016	0.0230	0.0093	0.0005334
445	0.030	0.4740	0.0298	0.0143	0.0009004
450	0.035	0.5537	0.0380	0.0193	0.0013243
455	0.031	0.6297	0.0480	0.0193	0.0014749
460	0.023	0.7080	0.0600	0.0162	0.0013707
465	0.017	0.7852	0.0739	0.0135	0.0012705
470	0.014	0.8603	0.0910	0.0117	0.0012373
475	0.012	0.9177	0.1126	0.0106	0.0012949
480	0.011	0.9656	0.1390	0.0104	0.0014915
485	0.010	0.9906	0.1693	0.0103	0.0017551
490	0.011	1.0000	0.2080	0.0113	0.0023541
495	0.014	0.9920	0.2586	0.0143	0.0037358
500	0.019	0.9660	0.3230	0.0184	0.0061601
505	0.024	0.9223	0.4073	0.0219	0.0096499
510	0.028	0.8629	0.5030	0.0246	0.0143288
515	0.033	0.7852	0.6082	0.0259	0.0200374
520	0.037	0.6996	0.7100	0.0256	0.0259292
525	0.040	0.6094	0.7932	0.0241	0.0314206
530	0.042	0.5193	0.8620	0.0219	0.0363641
535	0.044	0.4325	0.9149	0.0192	0.0406455
540	0.046	0.3517	0.9540	0.0161	0.0436114
545	0.047	0.2791	0.9803	0.0132	0.0464989
550	0.049	0.2157	0.9950	0.0106	0.0491079
555	0.052	0.1621	1.0000	0.0084	0.05208

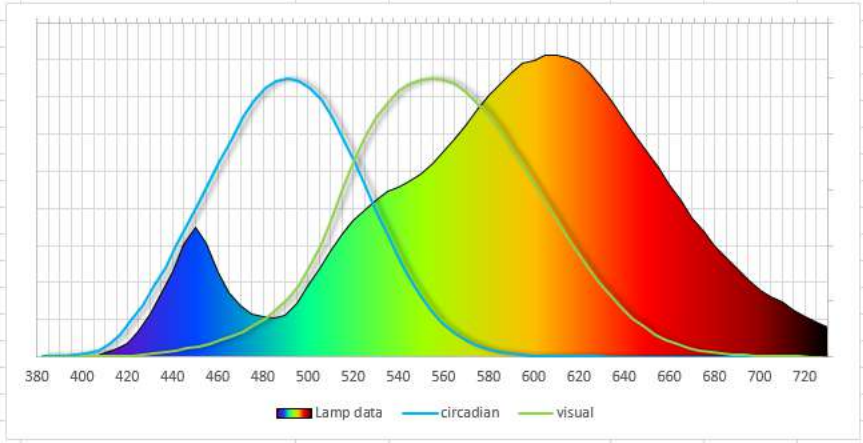
Source: Sample LED 2700 K

Melanopic Ratio: 0.445

Click here for data input

Instructions

1. Select built-in sample source, or user-entered source (above).
2. For user data, paste lamp spectral power distribution (5 nm increments) into Data sheet.
3. To add more user sources, insert columns to the left of User 2 on the Data sheet.
4. Multiply the Melanopic Ratio by measured or modeled lux to calculate equivalent melanopic lux.



INTERNATIONAL WELL BUILDING INSTITUTE™

Circadian | Data

Add a new Light Source using the SPD provided by the manufacturer

leducation.org

Equivalent Melanopic Lux (EML) Calculation: Walkthrough

PLEASE NOTE:

Wavelength results are on increments of 5

	A	B	C	D	E	F	O	P	Q
1	Wavelength	Sample LED 2700 K	Sample LED 4000 K	Sample Fluorescent 2950 K	Sample Fluorescent 4000 K	Sample Fluorescent 6500 K		Equal Energy Constant	
2	380	0	0	1.469086667	0.088942857	1.316893333		1.218	
3	385	0	0	1.65856	0.087871429	1.70446			
4	390	0	0	1.87856875	0.086866667	2.20519375		Insert columns to left of	
5	395	0	0	1.928986667	0.808844444	2.598086667		User 2 to add additional	
6	400	0	0	7.646746316	2.477175	10.73393659		sources.	
7	405	0	0.001459025	14.32851284	1.068	14.23881			
8	410	0.0012778	0.0026689	4.943801961	0.848142857	4.8469			
9	415	0.002231086	0.004704371	1.92730625	1.448585714	4.9355125			
10	420	0.003787683	0.008960765	1.81836	2.37715	5.644473333			
11	425	0.006768392	0.016133333	1.790826667	11.75395652	6.331693333			
12	430	0.01137806	0.026225	11.25750127	22.86331753	21.26188296			
13	435	0.016858824	0.040314286	40.61630899	6.404441176	44.453268			
14	440	0.02319	0.059346552	19.96685856	4.28675	19.90576394			
15	445	0.030214286	0.080282692	2.28079375	4.121685714	9.580693333			
16	450	0.03485	0.091275	1.960486667	4.23	10.34961333			
17	455	0.030726923	0.078393548	1.9239125	3.900814286	11.0898			
18	460	0.022845	0.060321212	1.92348	3.571657143	11.76982			
19	465	0.017192308	0.048725	2.004453333	3.187814286	12.39346667			
20	470	0.0136	0.039966667	2.0921875	3.132028571	12.94182941			
21	475	0.0115	0.03465	2.256786667	6.116533333	13.35968667			
22	480	0.010728571	0.032333333	2.382973333	10.72654615	13.68372667			
23	485	0.010366667	0.032428571	2.574125	9.566345455	13.9710625			
24	490	0.011316667	0.034471429	2.879453333	6.189957143	14.19598			
25	495	0.014446154	0.0381	3.177446667	3.3182	14.38378667			
26	500	0.019071429	0.04229	3.55624375	1.539942857	14.373225			
27	505	0.023692308	0.045542857	4.144153333	1.210757143	14.26049333			
28	510	0.028486667	0.0482	4.921406667	0.826914286	14.16479375			
29	515	0.032945455	0.0510625	5.86085	0.8258	14.02823333			
30	520	0.03652	0.053825	6.900866667	0.934114286	13.83470667			
31	525	0.0396125	0.055711111	7.89455625	5.608104545	13.63913125			
32	530	0.042185714	0.057933333	8.789933333	29.53066796	13.42994			
33	535	0.044428571	0.06026	9.621433333	75.41515328	13.27275333			
34	540	0.045714286	0.0628375	14.069025	61.27502029	17.82160549			
35	545	0.047433333	0.064533333	24.65848229	13.64250476	29.567098			
36	550	0.049357143	0.0664	21.1113713	3.532754545	18.44561818			
37	555	0.05208	0.068257143	13.12353684	1.391525	12.6899625			
38	560	0.0552	0.07	13.37198667	1.199028571	12.59653333			
39	565	0.058609091	0.0716	14.07691333	6.377933333	12.54113125			
40	570	0.062558333	0.073133333	14.91957059	15.62201143	12.42783333			
41	575	0.066666667	0.074283333	17.19122333	14.76690909	14.39066977			
42	580	0.07042	0.0753	18.82074	18.47862308	15.01757059			
43	585	0.0735125	0.0761	17.30793125	16.49222903	12.04747333			
44	590	0.076433333	0.0765	17.26683333	7.89120625	12.0537			
45	595	0.078933333	0.0765	17.64614375	4.030433333	12.0601375			

Circadian | Data

Add the wavelength results from manufacturer

leducation.org

Equivalent Melanopic Lux (EML) Calculation: Walkthrough

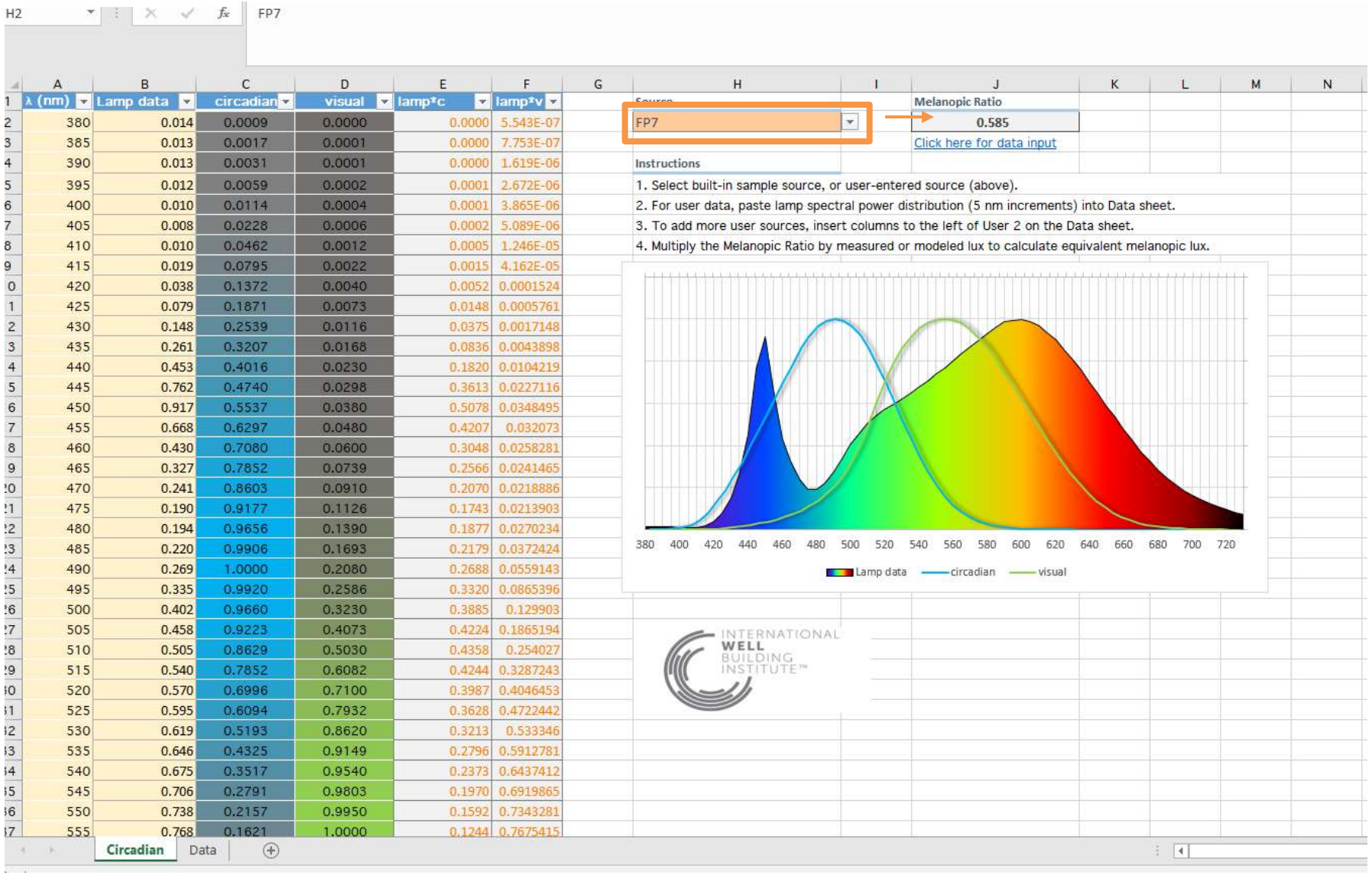
Wavelength	Sample LED 2700 K	Sample LED 4000 K	Sample Fluorescent 2950 K	Sample Fluorescent 4000 K	Sample Fluorescent 6500 K	FP7
380	0	0	1.469086667	0.088942857	1.316893333	0.013858
385	0	0	1.65856	0.087871429	1.70446	0.012922
390	0	0	1.87856875	0.086866667	2.20519375	0.013495
395	0	0	1.928986667	0.808844444	2.598086667	0.012313
400	0	0	7.646746316	2.477175	10.73393659	0.009662
405	0	0.001459025	14.32851284	1.068	14.23881	0.007951
410	0.0012778	0.0026689	4.943801961	0.848142857	4.8469	0.010301
415	0.002231086	0.004704371	1.92730625	1.448585714	4.9355125	0.019092
420	0.003787683	0.008960765	1.81836	2.37715	5.644473333	0.038091
425	0.006768392	0.016133333	1.790826667	11.75395652	6.331693333	0.078919
430	0.01137806	0.026225	11.25750127	22.86331753	21.26188296	0.147827
435	0.016858824	0.040314286	40.61630899	6.404441176	44.453268	0.260679
440	0.02319	0.059346552	19.96685856	4.28675	19.90576394	0.453126
445	0.030214286	0.080282692	2.28079375	4.121685714	9.580693333	0.762135
450	0.03485	0.091275	1.960486667	4.23	10.34961333	0.917092
455	0.030726923	0.078393548	1.9239125	3.900814286	11.0898	0.668188
460	0.022845	0.060321212	1.92348	3.571657143	11.76982	0.430468
465	0.017192308	0.048725	2.004453333	3.187814286	12.39346667	0.326746
470	0.0136	0.039966667	2.0921875	3.132028571	12.94182941	0.240587
475	0.0115	0.03465	2.256786667	6.116533333	13.35968667	0.189967
480	0.010728571	0.032333333	2.382973333	10.72654615	13.68372667	0.194385
485	0.010366667	0.032428571	2.574125	9.566345455	13.9710625	0.219979
490	0.011316667	0.034471429	2.879453333	6.189957143	14.19598	0.268793
495	0.014446154	0.0381	3.177446667	3.3182	14.38378667	0.334647
500	0.019071429	0.04229	3.55624375	1.539942857	14.373225	0.402177
505	0.023692308	0.045542857	4.144153333	1.210757143	14.26049333	0.457941
510	0.028486667	0.0482	4.921406667	0.826914286	14.16479375	0.505024
515	0.032945455	0.0510625	5.86085	0.8258	14.02823333	0.540487
520	0.03652	0.053825	6.900866667	0.934114286	13.83470667	0.569923
525	0.0396125	0.055711111	7.89455625	5.608104545	13.63913125	0.595366
530	0.042185714	0.057933333	8.789933333	29.53066796	13.42994	0.618731
535	0.044428571	0.06026	9.621433333	75.41515328	13.27275333	0.646312
540	0.045714286	0.0628375	14.069025	61.27502029	17.82160549	0.674781
545	0.047433333	0.064533333	24.65848229	13.64250476	29.567098	0.705893
550	0.049357143	0.0664	21.1113713	3.532754545	18.44561818	0.738055
555	0.05208	0.068257143	13.12353684	1.391525	12.6899625	0.767541
560	0.0552	0.07	13.37198667	1.199028571	12.59653333	0.802639
565	0.058609091	0.0716	14.07691333	6.377933333	12.54113125	0.836276
570	0.062558333	0.073133333	14.91957059	15.62201143	12.42783333	0.866826
575	0.066666667	0.074283333	17.19122333	14.76690909	14.39066977	0.897447
580	0.07042	0.0753	18.82074	18.47862308	15.01757059	0.92899
585	0.0735125	0.0761	17.30793125	16.49222903	12.04747333	0.958029
590	0.076433333	0.0765	17.26683333	7.89120625	12.0537	0.986486
595	0.078933333	0.0765	17.64614375	4.030433333	12.0601375	0.990118

Equal Energy Constant
1.218

Insert columns to left of User 2 to add additional sources.

Circadian | Data

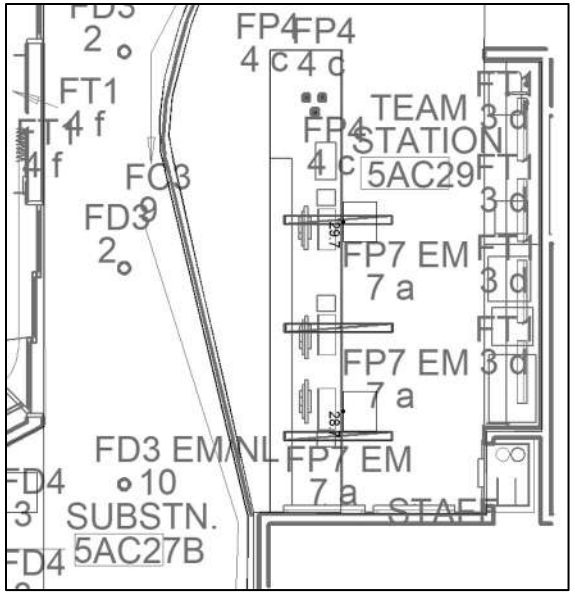
Equivalent Melanopic Lux (EML) Calculation: Walkthrough

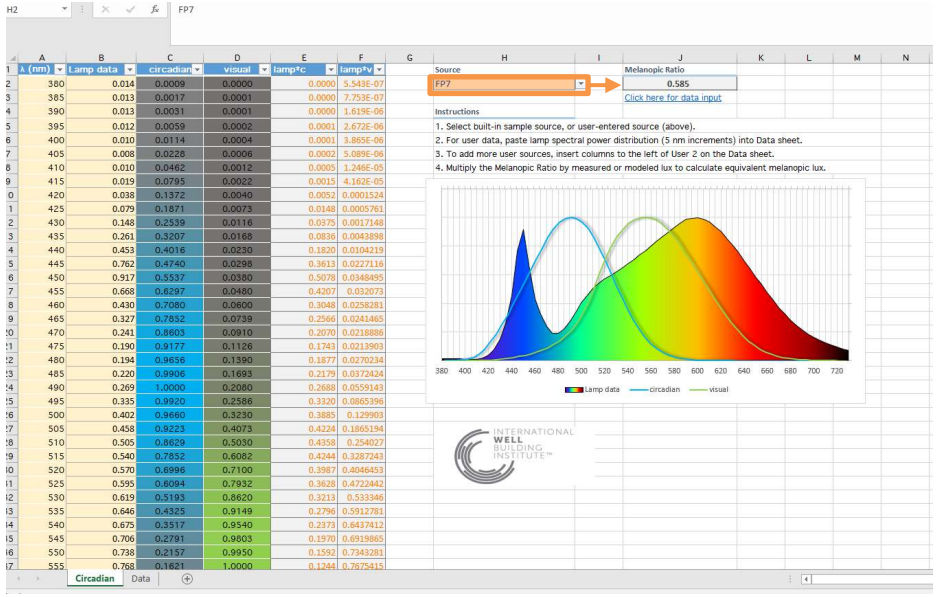


λ (nm)	Lamp data	circadian	visual	lamp*c	lamp*v
380	0.014	0.0009	0.0000	0.0000	5.543E-07
385	0.013	0.0017	0.0001	0.0000	7.753E-07
390	0.013	0.0031	0.0001	0.0000	1.619E-06
395	0.012	0.0059	0.0002	0.0001	2.672E-06
400	0.010	0.0114	0.0004	0.0001	3.865E-06
405	0.008	0.0228	0.0006	0.0002	5.089E-06
410	0.010	0.0462	0.0012	0.0005	1.246E-05
415	0.019	0.0795	0.0022	0.0015	4.162E-05
420	0.038	0.1372	0.0040	0.0052	0.0001524
425	0.079	0.1871	0.0073	0.0148	0.0005761
430	0.148	0.2539	0.0116	0.0375	0.0017148
435	0.261	0.3207	0.0168	0.0836	0.0043898
440	0.453	0.4016	0.0230	0.1820	0.0104219
445	0.762	0.4740	0.0298	0.3613	0.0227116
450	0.917	0.5537	0.0380	0.5078	0.0348495
455	0.668	0.6297	0.0480	0.4207	0.032073
460	0.430	0.7080	0.0600	0.3048	0.0258281
465	0.327	0.7852	0.0739	0.2566	0.0241465
470	0.241	0.8603	0.0910	0.2070	0.0218886
475	0.190	0.9177	0.1126	0.1743	0.0213903
480	0.194	0.9656	0.1390	0.1877	0.0270234
485	0.220	0.9906	0.1693	0.2179	0.0372424
490	0.269	1.0000	0.2080	0.2688	0.0559143
495	0.335	0.9920	0.2586	0.3320	0.0865396
500	0.402	0.9660	0.3230	0.3885	0.129903
505	0.458	0.9223	0.4073	0.4224	0.1865194
510	0.505	0.8629	0.5030	0.4358	0.254027
515	0.540	0.7852	0.6082	0.4244	0.3287243
520	0.570	0.6996	0.7100	0.3987	0.4046453
525	0.595	0.6094	0.7932	0.3628	0.4722442
530	0.619	0.5193	0.8620	0.3213	0.533346
535	0.646	0.4325	0.9149	0.2796	0.5912781
540	0.675	0.3517	0.9540	0.2373	0.6437412
545	0.706	0.2791	0.9803	0.1970	0.6919865
550	0.738	0.2157	0.9950	0.1592	0.7343281
555	0.768	0.1621	1.0000	0.1244	0.7675415

Equivalent Melanopic Lux (EML) Calculation: Walkthrough

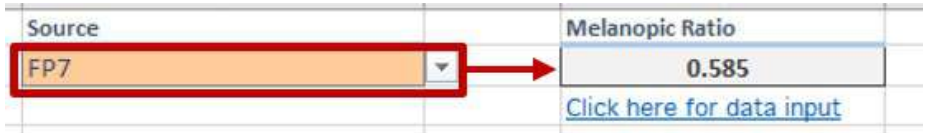
EML = LUX (ON VERTICAL EYE) * MELANOPIC RATIO





Linear Fixtures

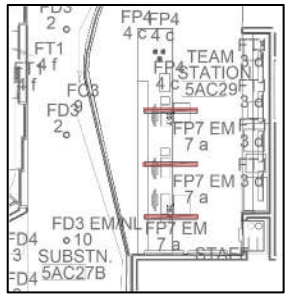
Result:
29.7 FC = 300 lux



EML = 300 LUX * 0.585 MR = **174**

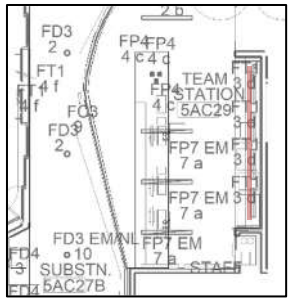
leducation.org

Equivalent Melanopic Lux (EML) Calculation: Walkthrough



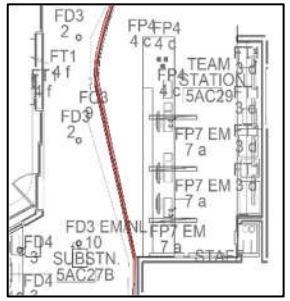
Linear Fixtures

Result:
297 FC = 300 lux



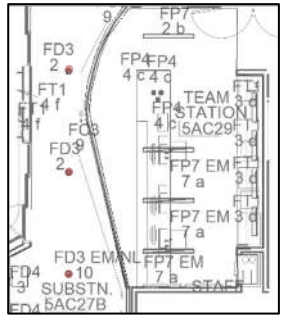
Task Light

Result:
0.2 FC = 2.5 lux



Cove Light

Result:
0.3 FC = 6.5 lux



Downlights

Result:
0.9 FC = 10 lux

	7AM-4PM	4PM-8PM	8PM-7AM
Linear Pendant	Min. output to 50%	Min. output to 50%	Max. output to 50%
Cove lights	100%	100%	Max. output to 50%
Task light	100%	100%	Max. output to 40%
Downlight	100%	Min. Output to 50%	Max. output to 50%
CIRCADIAN STIMULUS	0.3	0.2	0.1
EML	131	192	66

Healthcare Design and Collaborative Process

Client

Architects

Coordinate data from Lighting Designer to translate into project design

Healthcare staff

They understand their needs and the patients

Feedback on outcomes with designed circadian in recommended spaces

Lighting Designer

Educate Architect and client on how to achieve circadian entrainment

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Circadian Metrics

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References

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Pacific NorthWest National Laboratory – Andrea Wilkerson and Jessica Collier, PNNL Advanced Lighting Team
International WELL Building Institute – Gayathri Unnikrishnan, Vice President, Standard Development, Concept Lead for Light

Projects

CannonDesign, Northwell Health ASP, Manhasset, NY
Payette, Holyoke Soldiers Home, Holyoke, MA

Video

https://standard.wellcertified.com/light/circadian-lighting-design
https://v2.wellcertified.com/en/wellv2/light/feature/3
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5560620/#R11
https://www.youtube.com/watch?v=U3lKLPimF-o&list=PL_X9RKGy9RIZmgzoJwHZsQmpPW6O1fLu3&index=7

Tools

Webbased LRC CS Calculator: https://www.youtube.com/watch?v=d70aOYQUr48

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This concludes The American Institute of Architects Continuing Education Systems Course

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