

How to Use the Look-up Chart

This look-up chart provides a quick and easy way to estimate the potential average circadian stimulus (CS) value in a space using conventional lighting metrics. The following briefly describes the basic principles of the CS metric, the methodological assumptions underlying the calculations presented in the chart, and the way to determine the best estimate of CS that will be delivered to your designed space.

Methodology

When specifying lighting for the circadian system, more specifically, for circadian entrainment, it is important to consider light level, spectrum (color), timing and duration of exposure, and photic history (i.e., previous light exposures). The Lighting Research Center (LRC) uses circadian stimulus (CS) to estimate whether a lighting system can provide the levels of light necessary for affecting the circadian system. To calculate CS, it is important to know the spectral irradiance distribution of the light incident at the cornea. From this spectral irradiance distribution, it is then possible to calculate circadian light (CL_A), which is irradiance at the cornea weighted to reflect the spectral sensitivity of the human circadian system as measured by acute melatonin suppression after a 1-hour exposure. CS, in turn, is the calculated effectiveness of the spectrally weighted irradiance at the cornea from threshold ($CS = 0.1$) to saturation ($CS = 0.7$). It is important to keep in mind that the CS metric assumes a fixed duration of exposure (1 hour) and is agnostic with respect to timing and photic history. However, it is recommended that high circadian stimulus be provided during the day, especially in the morning hours.

Figure 1 shows the absolute sensitivity of the human circadian system plotted as a function of light level, where the spectral power distributions (SPDs) of different light sources used in previously published studies are weighted according to CL_A . As shown in Figure 1, the threshold for circadian activation is close to 0.1 and the saturation is close to 0.7. Our research shows that exposure to a CS of 0.3 or greater at the eye, for at least 1 hour in the early part of the day, is associated with better sleep and improved mood. A CS of 0.3 is equivalent to 30% melatonin suppression if that light was applied for 1 hour in the middle of the night when melatonin levels are high. It is being used as a surrogate for circadian system activation. It is important to keep in mind that although delivering a CS of 0.3 is typically recommended,

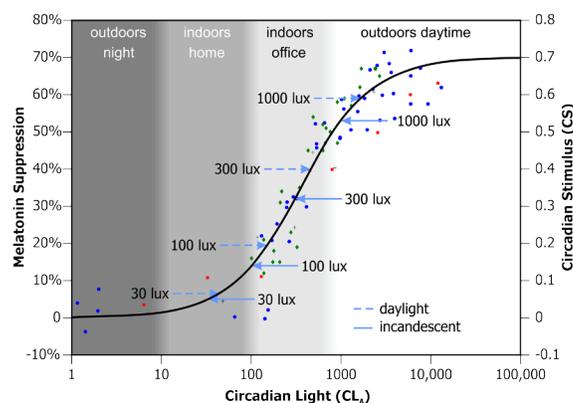


Figure 1. The absolute sensitivity of the human circadian system plotted as a function of light level, where the SPDs of various light sources used in previous published studies are weighted according to CL_A (x-axis). The right ordinate (y-axis), labeled circadian stimulus (CS), is scaled to be proportional to the left ordinate representing the relative amount of melatonin suppressed after exposing the retina for 1 hour, ranging from 0 (no suppression) to a maximum of 0.7 (70% suppression).

this value is not a universal, one-size-fits-all prescription for all situations and lighting systems.

Lower light levels, such as those that might be specified for horizontal illuminance in a given workspace, will achieve relatively lower CS values unless compensated for by an SPD with more power at shorter wavelengths. In this case, the space would require a light source that would emit more short-wavelength light. We found that when targeting an average horizontal illuminance of 300 lux, for example, an SPD emitting more short-wavelength (e.g., correlated color temperature [CCT] of 6000 K) light was needed to achieve a target CS of 0.3. For a targeted average horizontal illuminance of 400 lux, on the other hand, an SPD emitting less short-wavelength (e.g., CCT of 4500 K) light was capable of reaching the same CS. Changes in CS values can also be achieved by simply increasing or decreasing the system's light output while maintaining the same CCT. The key takeaway in this regard is that CS, and not simply CCT or light levels, is the correct metric to consider when determining how light affects the circadian system.

The values shown in the tables are based on a typical office space with a ceiling height of 9 feet above finished floor (Figure 2), using the following specifications:

- Standard reflectance values were assumed for the space: 80 percent for the ceiling, 50 percent for the walls, and 20 percent for the floor.
- Any blocking objects included in the model, such as desks and chairs, were assigned a reflectance value of 50 percent.
- The model employed 4-foot suspended linear luminaires, 2x4 recessed troffer luminaires, and recessed downlights.
- Three different distributions were considered for the suspended linear luminaires: direct/indirect, direct, and indirect.
- Fixture spacing in our calculations was based on a typical office layout and determined by the target horizontal illuminance, which in the accompanying CS tables ranges from 300 to 500 lux in 50-lux intervals.
- The relationship between horizontal and vertical illuminance levels has been estimated by calculating the average ratio of vertical illuminance to horizontal illuminance for a range of manufacturer's luminaire types.
- SPDs from eight different manufacturers were used to calculate the CS provided by the horizontal illuminance levels for the light emitting diode (LED) sources.



Figure 2. Typical office space assumed for the calculations shown in the lookup table.

Using the Chart

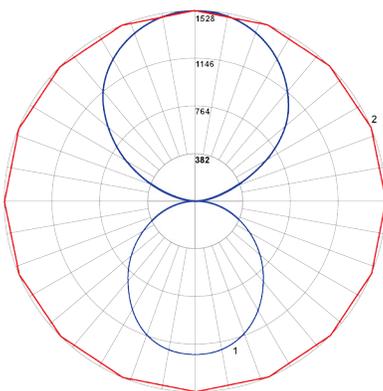
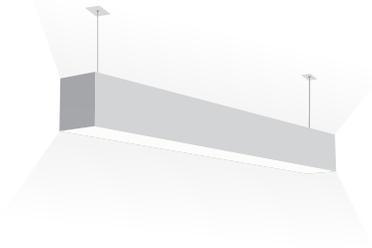


Figure 3. Photometric distribution of the direct-indirect luminaire employed for the calculations in the lookup table.

First, determine the particular source type (i.e., fluorescent or LED) and luminaire distribution (i.e., direct, indirect, or direct/indirect [Figure 3]) that will be used in the designed space, then locate the appropriate table based on those variables. Next, determine which nominal CCT will be used in the space. Each page of this document contains a table that shows the values for CS at the eye by targeted horizontal illuminance and source or manufacturer (LED). (In the case of LED luminaires, separate tables are provided for each CCT.) These individual tables can also be used for reverse search by locating the desired CS value in relation to horizontal illuminance and source or manufacturer.



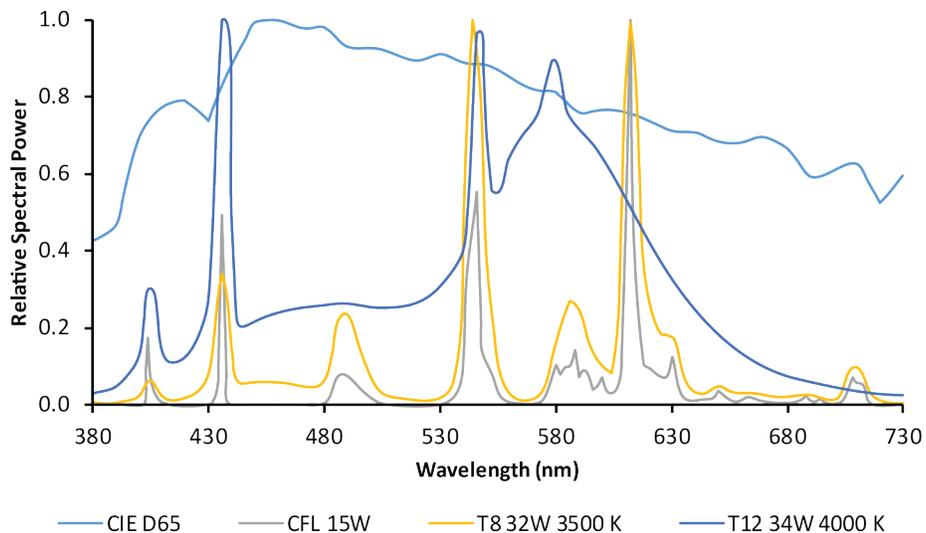
Source: Fluorescent Light
 Luminaire Type: Direct-Indirect
 Vertical:Horizontal Ratio = 0.65:1

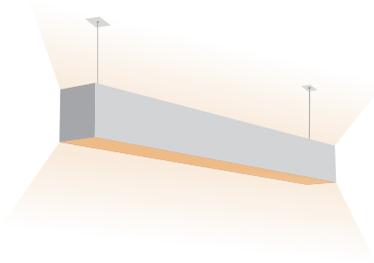
Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Fluorescent Light Sources			
	CIE D65	CFL 15 W	T8 32 W 3500 K	T12 34 W 4000 K
300	0.32	0.18	0.25	0.14
325	0.33	0.19	0.26	0.15
350	0.34	0.20	0.27	0.16
375	0.36	0.22	0.29	0.17
400	0.37	0.23	0.30	0.18
425	0.38	0.24	0.31	0.19
450	0.40	0.25	0.32	0.20
475	0.41	0.26	0.33	0.20
500	0.42	0.27	0.34	0.21

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

Fluorescent Light Sources





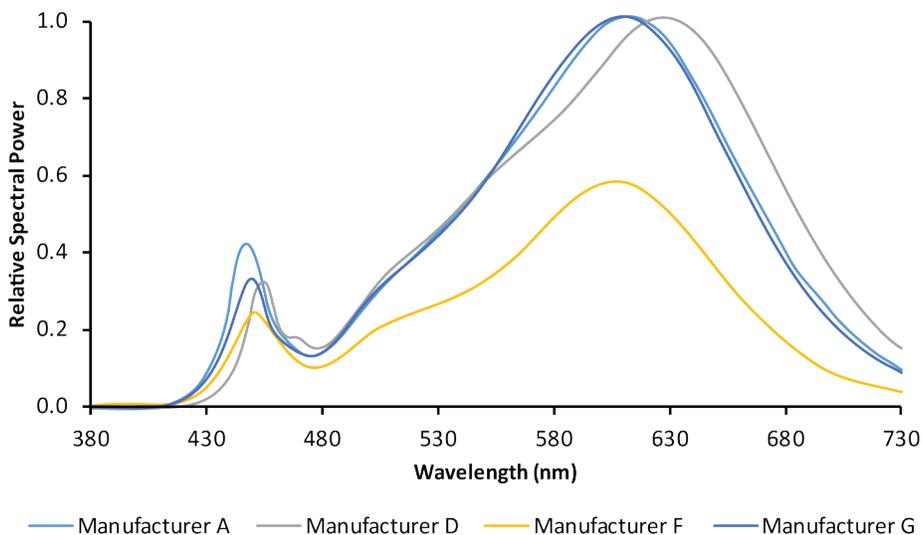
Source: LED, 2700 K
 Luminaire Type: Direct-Indirect
 Vertical:Horizontal Ratio = 0.65:1

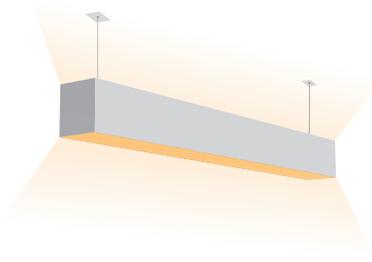
Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Manufacturer			
	A	D	F	G
300	0.21	0.20	0.23	0.20
325	0.22	0.22	0.24	0.21
350	0.23	0.23	0.25	0.22
375	0.24	0.24	0.27	0.24
400	0.26	0.25	0.28	0.25
425	0.27	0.26	0.29	0.26
450	0.28	0.27	0.30	0.27
475	0.29	0.28	0.31	0.28
500	0.30	0.29	0.32	0.29

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

LED- 2700 K Light Sources





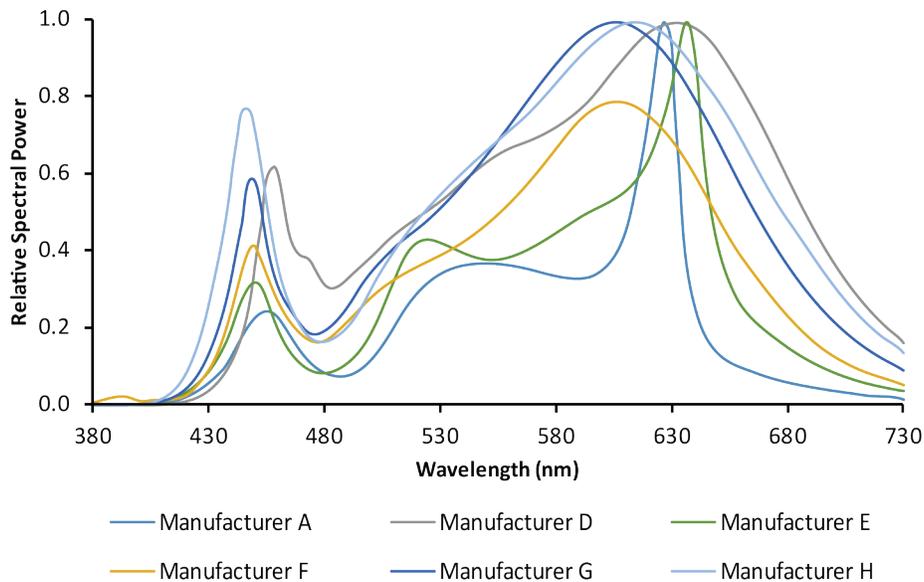
Source: LED, 3000 K
 Luminaire Type: Direct-Indirect
 Vertical:Horizontal Ratio = 0.65:1

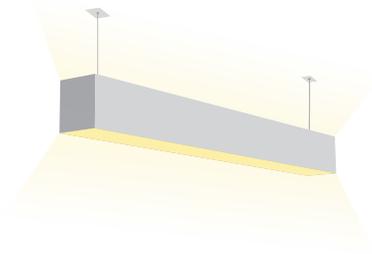
Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Manufacturer					
	A	D	E	F	G	H
300	0.23	0.26	0.24	0.24	0.23	0.12
325	0.25	0.27	0.25	0.25	0.25	0.13
350	0.26	0.29	0.26	0.27	0.26	0.14
375	0.27	0.30	0.28	0.28	0.27	0.14
400	0.29	0.31	0.29	0.29	0.28	0.15
425	0.30	0.33	0.30	0.30	0.30	0.16
450	0.31	0.34	0.31	0.31	0.31	0.17
475	0.32	0.35	0.32	0.32	0.32	0.18
500	0.33	0.36	0.33	0.33	0.33	0.19

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

LED- 3000 K Light Sources





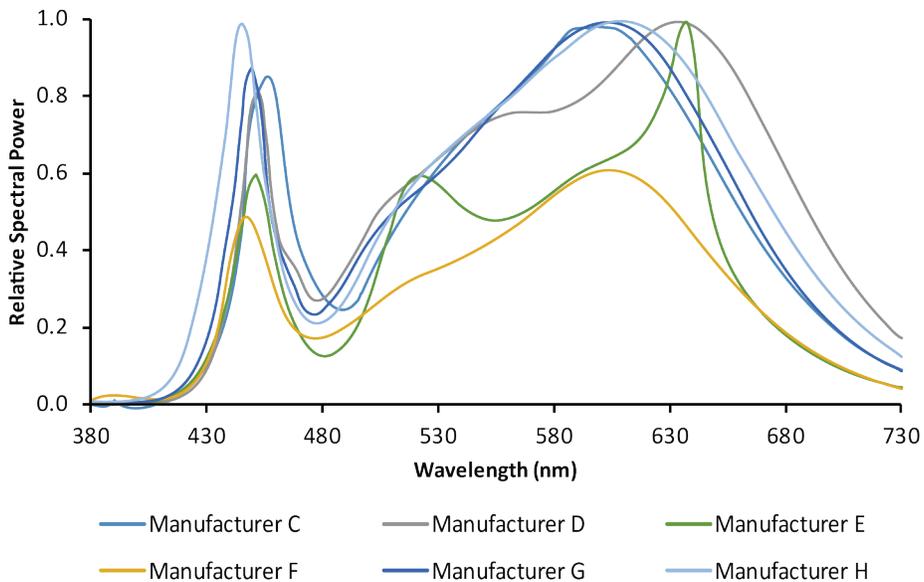
Source: LED, 3500 K
Luminaire Type: Direct-Indirect
Vertical:Horizontal Ratio = 0.65:1

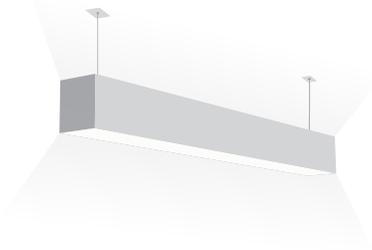
Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Manufacturer					
	C	D	E	F	G	H
300	0.12	0.13	0.12	0.15	0.13	0.15
325	0.13	0.14	0.13	0.16	0.14	0.17
350	0.14	0.15	0.14	0.18	0.15	0.18
375	0.15	0.16	0.15	0.19	0.16	0.19
400	0.16	0.17	0.16	0.20	0.17	0.20
425	0.17	0.17	0.17	0.21	0.17	0.21
450	0.17	0.18	0.18	0.22	0.18	0.22
475	0.18	0.19	0.19	0.22	0.19	0.23
500	0.19	0.20	0.20	0.23	0.20	0.23

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

LED- 3500 K Light Sources





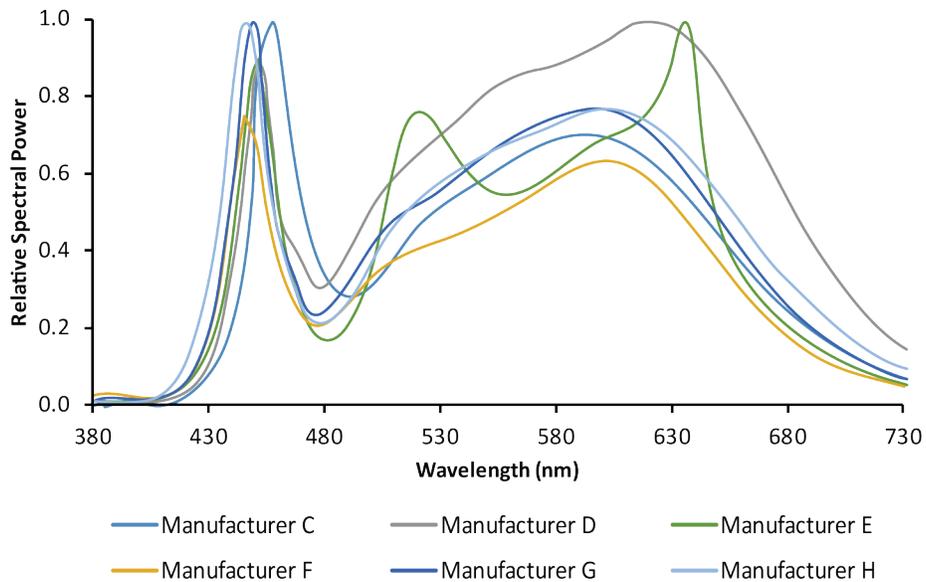
Source: LED, 4000 K
Luminaire Type: Direct-Indirect
Vertical:Horizontal Ratio = 0.65:1

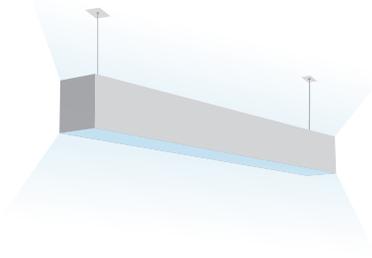
Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Manufacturer					
	C	D	E	F	G	H
300	0.20	0.13	0.17	0.20	0.18	0.20
325	0.21	0.14	0.18	0.21	0.20	0.21
350	0.22	0.15	0.19	0.23	0.21	0.22
375	0.24	0.16	0.20	0.24	0.22	0.24
400	0.25	0.17	0.22	0.25	0.23	0.25
425	0.26	0.17	0.23	0.26	0.24	0.26
450	0.27	0.18	0.24	0.27	0.25	0.27
475	0.28	0.19	0.25	0.28	0.26	0.28
500	0.29	0.20	0.25	0.29	0.27	0.29

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

LED- 4000 K Light Sources





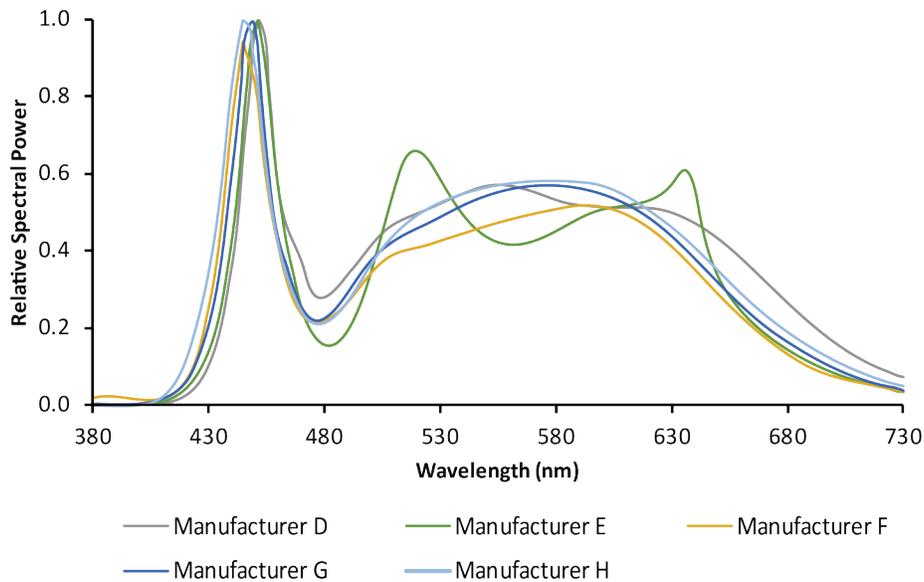
Source: LED, 5000 K
 Luminaire Type: Direct-Indirect
 Vertical:Horizontal Ratio = 0.65:1

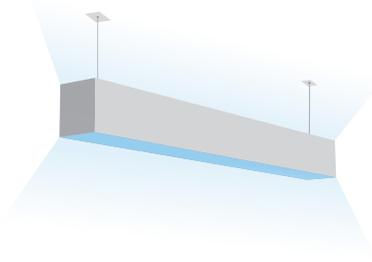
Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Manufacturer				
	D	E	F	G	H
300	0.24	0.24	0.26	0.24	0.25
325	0.25	0.26	0.28	0.25	0.26
350	0.26	0.27	0.29	0.27	0.28
375	0.28	0.28	0.30	0.28	0.29
400	0.29	0.30	0.32	0.29	0.30
425	0.30	0.31	0.33	0.30	0.31
450	0.31	0.32	0.34	0.32	0.32
475	0.32	0.33	0.35	0.33	0.33
500	0.33	0.34	0.36	0.34	0.34

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

LED- 5000 K Light Sources





Source: LED, 6500 K
 Luminaire Type: Direct-Indirect
 Vertical:Horizontal Ratio = 0.65:1

Circadian Stimulus (CS) at the Eye

Horizontal Illuminance (lux)	Manufacturer			
	A	D	E	F
300	0.28	0.30	0.31	0.31
325	0.29	0.32	0.32	0.32
350	0.30	0.33	0.34	0.34
375	0.32	0.35	0.35	0.35
400	0.33	0.36	0.36	0.37
425	0.34	0.37	0.38	0.38
450	0.35	0.38	0.39	0.39
475	0.36	0.39	0.40	0.40
500	0.37	0.40	0.41	0.41

Values in **BOLD** meet or exceed the recommended CS of 0.3 or higher.

LED- 6500 K Light Sources

