photonfy
by LEDMOTIVE

Report created on: 14/10/2020, 21:31:52
Spectrum name: Measured LED Source
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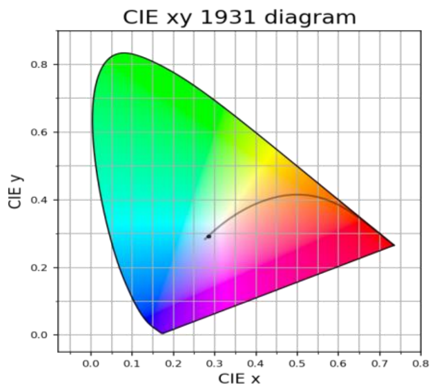
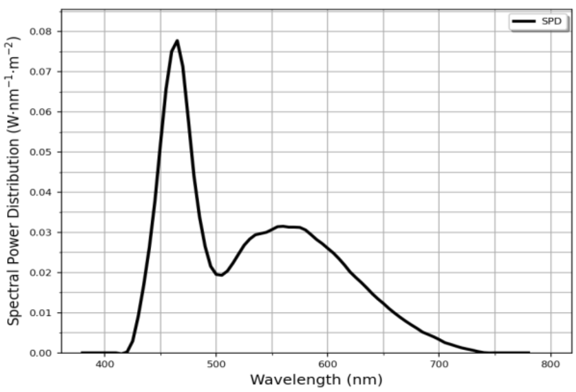
https://ledmotive.com/photonfy
https://photonfy.com

Report section: GENERAL

CIE1931-xy diagram and Spectral Power Distribution





CIE1931-xy diagram and Spectral Power Distribution

CCT, Δuv, and Illuminance

CCT (K)	Δuv
9268	-1,16E-03

CIE Color Rendering Index

R_a	R_9
85	38,67

IES TM30-18

R_f	R_g
78,58	87,35

Color coordinates

CIE 1931 XYZ	CIE 1931 xy	CIE 1976 u'v'	sRGB
(2.91, 2.97, 4.30)	(0.2857, 0.2921)	(0.1926, 0.4431)	(46, 48, 57)

General glossary

CCT: Correlated Color Temperature in Kelvin degrees (K). More info: https://en.wikipedia.org/wiki/Color_temperature#Correlated_color_temperature

Illuminance: in lux (lx), total luminous flux incident on the sensor diffuser surface, per unit area. It is a measure of how much the in cident light illuminates the surface, wavelength-weighted by the luminosity function to correlate with human brightness perception. More info: https://en.wikipedia.org/wiki/Illuminance

CIE 1931 (X,Y,Z) color space: The CIE XYZ color space encompasses all color sensations that are visible to a person with average eyesight. That is why CI E XYZ (Tristimulus values) is a device-invariant representation of color. It serves as a standard reference against which many other color spaces are defined. A set of color -matching functions, like the spectral sensitivity curves of the LMS color space, but not restricted to non-negative sensitivities, associates physically produced light spectra with specific tristimulus values. More info: https://en.wikipedia.org/wiki/CIE_1931_color_space

CIE 1931 (x,y) coordinates: The concept of color can be divided into two parts: brightness and chromaticity. The CIE XYZ color space was deliberately designed so that the Y parameter is a measure of the luminance of a color. The chromaticity is then specified by the two derived parameters x and y, two of the three normalized values being functions of a ll three tristimulus values X, Y, and Z. More info: https://en.wikipedia.org/wiki/CIE_1931_color_space

CIE 1976 (u',v') coordinates: The L*u*v* color space (also referred to as the CIELUV space) is one of the uniform color spaces defined by the CIE in 1976. (u', v') are the 2D chromaticity coordinates in this space. More info: https://en.wikipedia.org/wiki/CIELUV

sRGB: sRGB is an RGB color space that HP and Microsoft created cooperatively in 1996 to use on monitors, printers, and the Web. More info: https://en.wikipedia.org/wiki/SRGB

CIE CRI (Ra): is a quantitative measure of the ability of a light source to reveal the colors of various objects faithfully in compariso n with an ideal or natural light source. Light sources with a high CRI are desirable in color-critical applications such as neonatal care and art restoration. Ra is the average value of R1â€"R8, other values from R9 to R15 are m issing in Ra calculation, including R9 "saturated red", R13 "skin color (light)", and R15 "skin color (medium)", which are all difficult colors to faithfully reproduce. More info: https://en.wikipedia.org/wiki/Color_rendering_index

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IES TM 30-18 (Rg): Rg measures the average gamut shift (hue/saturation) of the source. A graphical representation of Rg is also usually provided to visually represent which colors are washed out or more vivid due to the light source. More info: https://www.energy.gov/sites/prod/files/2016/04/f30/tm -30_fact-sheet.pdf

SPD: Spectral power distribution (the visible range spans 380nm-780nm).

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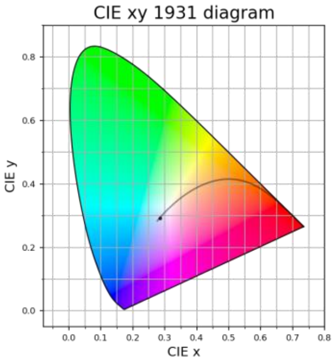
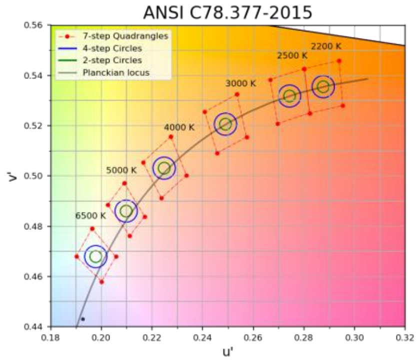
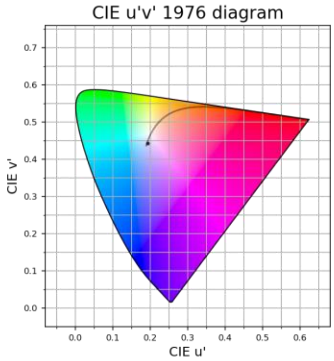
Report section: COLOR QUALITY

CIE1931-xy, CIE1976-u'v' spaces and ANSI C78.377-2015 Chomaticity of SSL products







CCT, Δuv, and Illuminance

CCT (K)	Δuv	Lux (lx)
9268	-1,16E-03	2.031,37

Color coordinates

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(2.91, 2.97, 4.30)	(0.2857, 0.0000)	(0.1926, 0.4431)	(46, 48, 57)

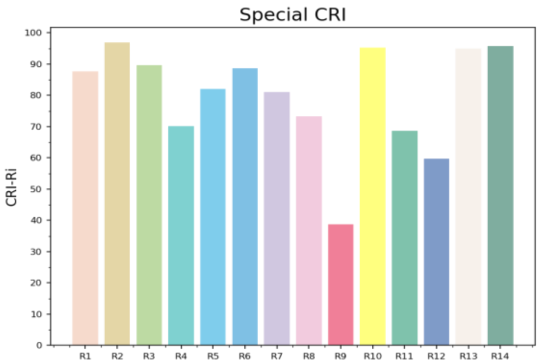
Dominant wavelength and purity

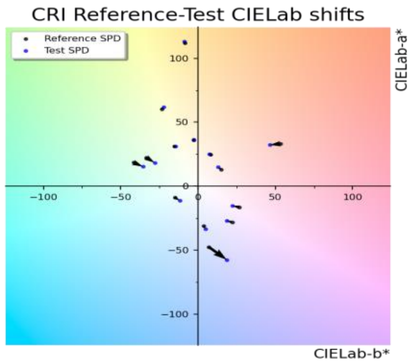
λ (nm)	Purity (%)
480	20,01

Other color spaces and names

HSV	CMYK	HEX Color	Human-readable	Nearest Munsell chip
(229.091, 0.193, 0.224)	(0.193, 0.158, 0.000, 0.776)	#2E3039	Crayola Outer Space	5PB 7/8

General and special CIE CRI indexes and associated CIE-L*a*b* color shifts

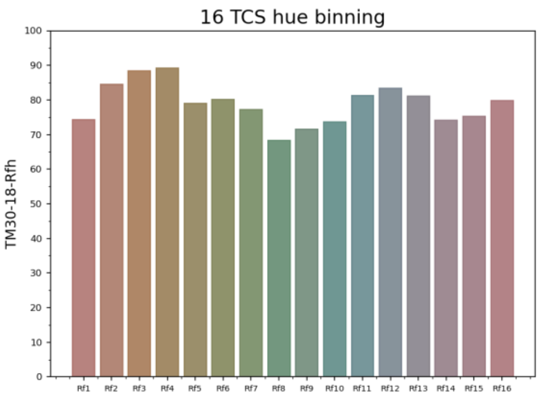


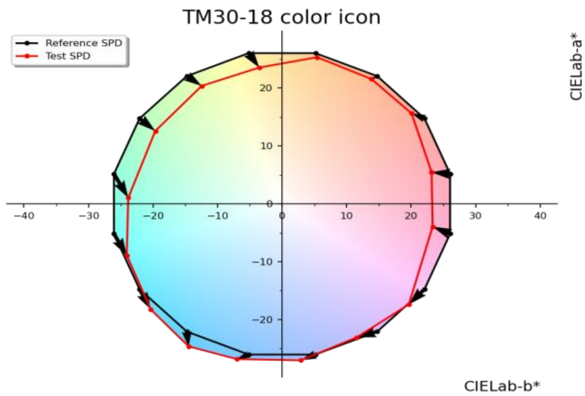


General and Special CRI values

R_a	R_1	R_2	R_3	R_4
85,15	87,71	96,94	89,71	70,15
R_5	R_6	R_7	R_8	R_9
81,98	88,60	81,00	73,27	38,67
R_{10}	R_{11}	R_{12}	R_{13}	R_{14}
95,27	68,69	59,73	94,96	95,78

IES TM38-18 Rf, Rg, Rfh binning and color icon saturation distortion



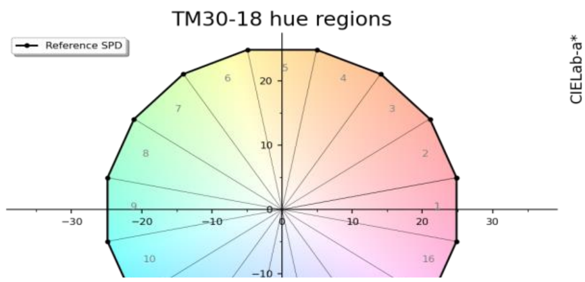


TM30-18 Rf and Rg values

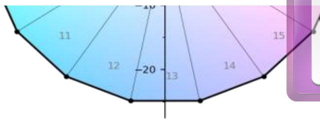
R_f	R_g
78,58	87,35

TM30-18 Rf and Rg values

R_{fh1}	R_{fh2}	R_{fh3}	R_{fh4}
74,35	84,45	88,46	89,20
R_{fh5}	R_{fh6}	R_{fh7}	R_{fh8}
79,00	80,18	77,23	68,33
R_{fh9}	R_{fh10}	R_{fh11}	R_{fh12}
71,59	73,70	81,21	83,40
R_{fh13}	R_{fh14}	R_{fh15}	R_{fh16}



81,07	74,13	75,21	79,76



Glossary of important terms related to color quality

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sRGB: sRGB is an RGB color space that HP and Microsoft created cooperatively in 1996 to use on monitors, printers, and the Web. More info: https://en.wikipedia.org/wiki/SRGB

HEX color:

HSV color: HSV (hue, saturation and Value]) is an alternative representation of the RGB color model, designed in the 1970s by computer graphics researchers to more closely align with the way human vision perceives color-making attributes. In these models, colors of each hue are arranged in a radial slice, around a central axis of neutral colors which ranges from black at the bottom to white at the top. More info: https://en.wikipedia.org/wiki/HSL_and_HSV

CMYK color: The CMYK color model is a subtractive color model, based on the CMY color model, used in color printing, and is also used to describe the printing process itself. CMYK refers to the four ink plates used in some color printers: cyan, magenta, yellow, and key (black). More info: https://en.wikipedia.org/wiki/CMYK_color_model

Human readable color: Human friendly manner to name a color as opposed to using color spaces.

Nearest Munsell: It provides the nearest Munsell chip to the color of the SPD under study.

Dominant wavelength: In nanometers (nm), is the wavelength of the monochromatic spectral light that evokes an identical perception of hue. More info: https://en.wikipedia.org/wiki/Dominant_wavelength

Spectral purity: Expressed as a percentage, it refers to the quantification of the monochromaticity of a given light sample. This is a particularly important parameter in areas like laser operation and time measurement. Spectral purity is easier to achieve in devices that generate visible and ultraviolet light, since higher frequency light results in greater spectral purity. More info: https://en.wikipedia.org/wiki/Spectral_purity

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Color and CCT binning. **ANSI C78.377-2017**: Standard that specifies the range of chromaticities recommended for general lighting with solid state lighting (SSL) products, as well as to ensure that the white light chromaticities of the products can be communicated to consumers. More info: https://www.techstreet.com/standards/ansi-c78-377-2017?product_id=1986630

CIE Special CRI: Particular CRI values for the different samples TCS 1-14 described in the method. More info: https://en.wikipedia.org/wiki/Color_rendering_index

CIE L*a*b* space: CIE L*a*b* (CIELAB) is a color space specified by the International Commission on Illumination (CIE). It describes all the colors visible to the human eye and was created to serve as a device-independent model to be used as a reference. The three coordinates of CIELAB represent the lightness of the color (L* = 0 yields black and L* = 100 indicates diffuse white; specular white may be higher), its position between red/magenta and green (a*, negative values indicate green while positive values indicate magenta) and its position between yellow and blue (b*, negative values indicate blue and positive values indicate yellow). The asterisk (*) after L, a and b are pronounced star and are part of the full name, since they represent L*, a* and b*, to distinguish them from Hunter's L, a, and b. More info: https://en.wikipedia.org/wiki/CIELAB_color_space

TM30-18 hue regions: In some cases, it may be necessary to specify numerical values for specific hue regions, such as red. The measures Rf,hj and Rcs,hj (where j indicates the number of the hue bin) correspond to the fidelity and chroma change for the average chromaticity in each of 16 hue bins. The bins are numbered in a counterclockwise order beginning with the positive a' axis of the CAM02-UCS. For example, Rf,h1 corresponds to the fidelity in hue bin 1, which is red. Rf,h1 is correlated with the CIE R9 value, but does not share the same scale. All fidelity values in TM30 are scaled from 0 to 100, with 100 indicating an exact match with the reference. More info: https://www.energy.gov/sites/prod/files/2016/04/f30/tm-30_fact-sheet.pdf

Report section: HEALTH AND WELLBEING

Classical α-opic related quantities from Lucas et al. See https://doi.org/10.1177%2F0748730411409719

EML - Effective Melanopic Lux (lx*)

EML (lx*)
2.642,48

Equivalent α-opic illuminance

Ez (lx*)
2.642,48

Er (lx*)
2.444,74

Esc (lx*)
2.582,05

Emc (lx*)
2.224,23

Elc (lx*)
2.030,93

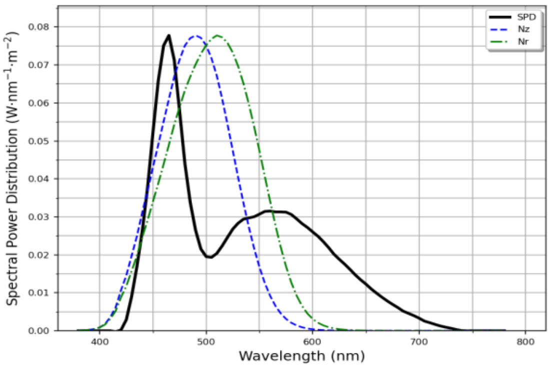
Each *equivalent α-opic illuminance* (symbol E_α; unit: α-opic + lux, lx, lumen per square metre, $lm.m^{-2}$) specifies a photometric quantity related to the spectral power distribution of irradiance $E_{e,\lambda}(\lambda)$ by the following equation. The absolute sensitivity is identical to photopic illuminance for light with an equal-energy spectral power distribution.

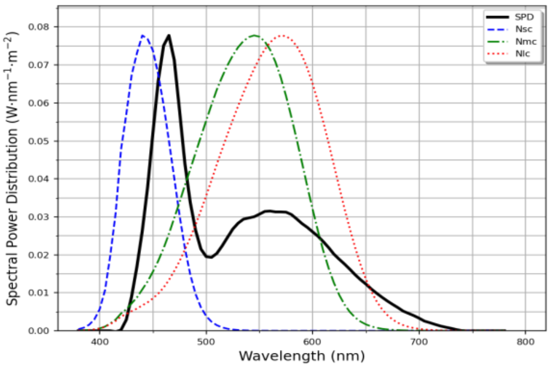
$$E_\alpha = K_m \int E_{e,\lambda}(\lambda)\, N_\alpha(\lambda)\, d\lambda \cdot \int V(\lambda)\, d\lambda \,/ \int N_\alpha(\lambda)\, d\lambda \qquad \text{(A1.1), where}$$

- λ is the wavelength of the radiation
- $K_m = 683.002$ lm/W, the maximum spectral *luminous efficacy**
- $V(\lambda)$ is the *spectral luminous efficacy** function for photopic vision
- $E_{e,\lambda}(\lambda)$ is the spectral power distribution
- $N_\alpha(\lambda)$ is the α-opic sensitivity curve ***with arbitrary normalisation***.

α specifies the retinal photopigment for a given organism. For example, the five human variants are:
cyanopic, relating to the s-cone photopigment
chloropic, relating to the m-cone photopigment
erythropic, relating to the l-cone photopigment
rhodopic, relating to rhodopsin
melanopic, relating to melanopsin

*Please see also: https://dx.doi.org/10.1016/j.tins.2013.10.004





CIE S 026 metrology for ipRGC-influenced responses to light (2018). See https://cie.co.at/news/launch-cie-s-026-toolbox-and-user-guide

Melanopic equivalent daylight (D65) illuminance, lx

M-EDI
2.393,20

Melanopic efficacy of luminous radiation, mW.lm-1

M-ELR
1,56

Melanopic Daylight efficacy ratio

M-DER
1,18

Melanopic irradiance, W/m2

M-I
3,17

From CIE S 026:2018
α-opic (α) may represent any one of S-cone-opic (sc), M-cone-opic (mc), L-cone-opic (lc), rhodopic (rh) and melanopic (mel)
$s_\alpha(\lambda) = s_{e,\alpha}(\lambda)$ = α-opic spectral weighting function (action spectrum)
$K_{\alpha,v}$ = α-opic efficacy of luminous radiation, **α-opic ELR**
$K^{D65}_{\alpha,v}$ = α-opic ELR for daylight (D65)
$\gamma^{D65}_{\alpha,v}$ = α-opic daylight (D65) efficacy ratio, **α-opic DER**
$E_\alpha = E_{e,\alpha}$ = α-opic irradiance (*i.e.* weighted by $s_\alpha(\lambda)$)
$E^{D65}_{v,\alpha}$ = α-opic equivalent daylight (D65) illuminance, **α-opic EDI**
$L_\alpha = L_{e,\alpha}$ = α-opic radiance (*i.e.* weighted by $s_\alpha(\lambda)$)
$L^{D65}_{v,\alpha}$ = α-opic equivalent daylight (D65) luminance, **α-opic EDL**

Melanopic/Photopic MP ratio. See https://www.energy.gov/sites/prod/files/2020/03/f72/ssl-mp-ratios_lda_feb2020.pdf

MP ratio (WELL v2-2019 Standard, Illuminant E as reference)

MP WELL
0,7688

MP ratio (CIE Standard, Illuminant D65 as reference)

MP CIE
0,8488

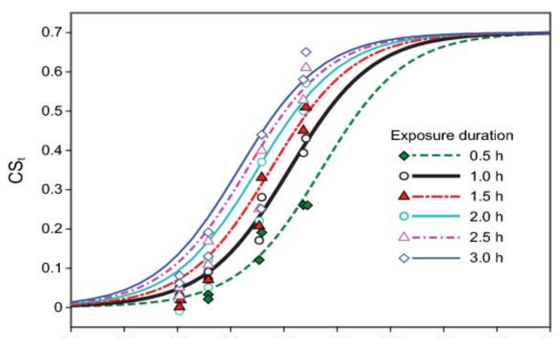
Rensselaer Lighting Research Center Circadian Stimulus and Cicadian Light metris
See: https://www.nature.com/articles/s41598-020-70619-5

Circadian Stimulus

CS
0,66

Circadian Light

CLA
4.709,02



0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
$\log10(CL_A)$

Glossary of important terms related to health

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Effective Melanopic Lux (**EML**): The biological effects of light on humans can be measured in Equivalent Melanopic Lux (EML), a proposed alternate metric that is weighted to the ipRGCs instead of to the cones, which is the case with traditional lux. During Performance Verification, EML is measured on the vertical plane at eye level of the occupant. More info: https://standard.wellcertified.com/light/circadian-lighting-design

Circadian Stimulus (**CS**): Estimate whether a lighting system can provide the levels of light necessary for affecting the circadian system. More precisely, CS is defined as 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. More info: https://www.lrc.rpi.edu/programs/lightHealth/pdf/LookUpTable_Recessed-Downlight.pdf

Circadian Light (**CLA**): Is the 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. More info: https://www.lrc.rpi.edu/programs/lightHealth/pdf/LookUpTable_Recessed-Downlight.pdf

Report section: DAMAGE CAUSED BY OPTICAL RADIATION

CIE CIE 157:2004 Control of damage to museum objects by optical radiation

CIE 157:2004 damage to museum objects, basic definitions:

- The fundamental quantity associated to the damage that a light source [with spectral irradiance $E_{e\lambda}(\lambda)$] causes to an object, is its **effective damage irradiance E_{dm}**, which is given by:

$$E_{dm} = \int_{300}^{780} E_{e\lambda}(\lambda) \cdot s_{dm,rel}(\lambda) \cdot d\lambda \quad \left[\frac{W}{m^2}\right]$$

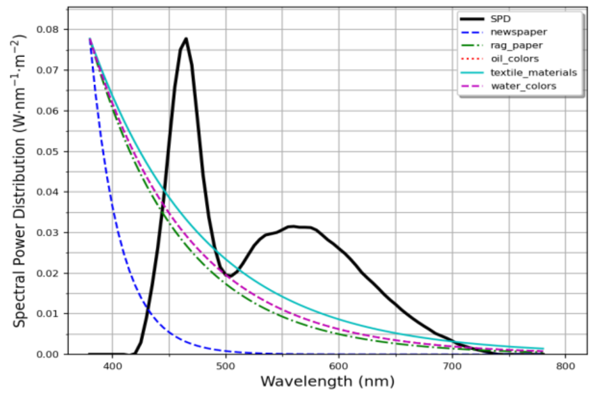
  Where $s_{dm,rel}(\lambda)$ are the CIE damage (exponential) functions associated with the material under study (see figure on the right).
- The **threshold radiation $H_{s,dm}$** describes the amount of radiation energy that must act on an object until a visible change in the object's color occurs. For a given material, its value can be found in the document CIE 157:2004.
- The **potential damage P_{dm}** is the fixed proportion between effective irradiance E_{dm} and illuminance E and applies to one lighting situation and one object or material:

$$P_{dm} = \frac{E_{dm}}{E} \left[\frac{mW}{lm}\right]$$

- Finally, the **threshold exposure or critical radiation time t_s**, the time after which there is a risk of visible damage or color change:

$$t_s = \frac{H_{s,dm}}{P_{dm} \cdot E} \; [hours]$$

*See http://cie.co.at/publications/control-damage-museum-objects-optical-radiation



Material: NEWSPAPER. Effective Irradiance, Potential damage and Threshold Exposure time

Newspaper

Newspaper
Effective Irradiance (Edm)
Edm [W/m²]
0,01
Damage potential (Pdm)
Pdm [mW/lm]
0,00
Threshold exposure (ts)
ts [hours]
662
Illuminance (E)
Illuminance [lx]
2.031,37

				Illuminance [lx]				
	50	150	300	500	1000	2000	5000	20000
Pdm [mW/lm]				Threshold exposure [hours]				
0,01	10000	3334	1667	1000	500	250	100	25
0,05	2000	667	334	200	100	50	20	5
0,10	1000	334	167	100	50	25	10	3
0,11	910	304	152	91	46	23	10	3
0,12	834	278	139	84	42	21	9	3
0,13	770	257	129	77	39	20	8	2
0,14	715	239	120	72	36	18	8	2
0,15	667	223	112	67	34	17	7	2
0,16	625	209	105	63	32	16	7	2
0,17	589	197	99	59	30	15	6	2
0,18	556	186	93	56	28	14	6	2
0,20	500	167	84	50	25	13	5	2
0,23	435	145	73	44	22	11	5	2
0,27	371	124	62	38	19	10	4	1
0,54	186	62	31	19	10	5	2	1

Material: RAG PAPER. Effective Irradiance, Potential damage and Threshold Exposure time

Rag paper

Rag paper
Effective Irradiance (Edm)
Edm [W/m²]
0,56
Damage potential (Pdm)
Pdm [mW/lm]
0,27
Threshold exposure (ts)
ts [hours]
2157
Illuminance (E)
Illuminance [lx]
2.031,37

				Illuminance [lx]				
	50	150	300	500	1000	2000	5000	20000
Pdm [mW/lm]				Threshold exposure [hours]				
0,01	2400000	800000	400000	240000	120000	60000	24000	6000
0,05	480000	160000	80000	48000	24000	12000	4800	1200
0,10	240000	80000	40000	24000	12000	6000	2400	600
0,11	218182	72728	36364	21819	10910	5455	2182	546
0,12	200000	66667	33334	20000	10000	5000	2000	500
0,13	184616	61539	30770	18462	9231	4616	1847	462
0,14	171429	57143	28572	17143	8572	4286	1715	429
0,15	160000	53334	26667	16000	8000	4000	1601	401
0,16	150000	50000	25000	15000	7500	3750	1500	375
0,17	141177	47059	23530	14118	7059	3530	1412	353
0,18	133334	44445	22223	13334	6667	3334	1334	334
0,20	120000	40000	20000	12000	6000	3000	1200	300
0,23	104348	34783	17392	10435	5218	2609	1044	261
0,27	88889	29630	14815	8889	4445	2223	889	223
0,54	44445	14815	7408	4445	2223	1112	445	112

Material: OIL COLORS. Effective Irradiance, Potential damage and Threshold Exposure time

Oil Colors

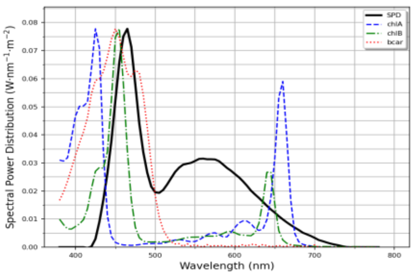
Oil colors

				Illuminance [lx]				
	50	150	300	500	1000	2000	5000	20000
Pdm [mW/lm]				Threshold exposure [hours]				
0,01	1700000	566667	283334	170000	85000	42500	17000	4250

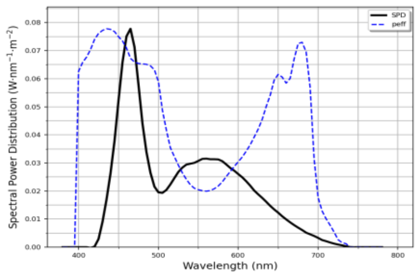
Report section: HORTICULTURE LIGHTING METRICS

Plant pigment absorption and PAR action spectrum

Absorption spectra for chlorophyll-A, chlorophyll-B, and carotenoids



PAR action spectrum (oxygen evolution per incident photon) of an isolated chloroplast



PPFD and YPFD: Photosynthetic Photon Flux density and Yield Photon Flux density

PPFD in the whole PAR zone (400-700 nm), in µmol/s/m²

PPFD PAR (400-700 nm)
31,96

PPFD in the UVA zone (350-400 nm), in µmol/s/m²

PPFD UVA (350-400 nm)
0,00

PPFD in the BLUE zone (400-500 nm), in µmol/s/m²

PPFD BLUE (400-500 nm)
12,00

PPFD in the GREEN zone (500-600 nm), in µmol/s/m²

PPFD GREEN (500-600 nm)
12,73

PPFD in the RED zone (600-700 nm), in µmol/s/m²

PPFD RED (600-700 nm)
7,24

PPFD in the NIR zone (700-800 nm), in µmol/s/m²

PPFD NIR (700-800 nm)
0,28

YPFD in the whole PAR zone (400-700 nm), in µmol/s/m²

YPFD PAR (400-700 nm)
26,48

YPFD in the UVA zone (350-400 nm), in µmol/s/m²

YPFD UVA (350-400 nm)
0,00

YPFD in the BLUE zone (400-500 nm), in µmol/s/m²

YPFD BLUE (400-500 nm)
8,58

YPFD in the GREEN zone (500-600 nm), in µmol/s/m²

YPFD GREEN (500-600 nm)
11,00

YPFD in the RED zone (600-700 nm), in µmol/s/m²

YPFD RED (600-700 nm)
6,90

YPFD in the NIR zone (700-800 nm), in µmol/s/m²

YPFD NIR (700-800 nm)
0,08

Ratios and and DLI (Daily Light Integral)

Red-to-Blue PPDF ratio

R-B ratio
0,60

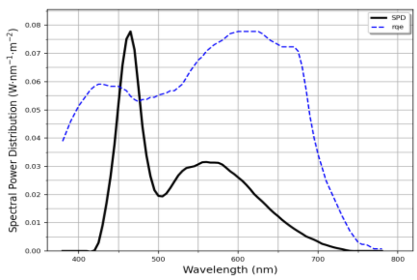
Red-to-NIR PPDF ratio

R-NIR ratio
25,45

Daily Light Integral (DLI), in mol/m²/day

DLI
2,76

Photon-weighted curve to convert PPF to YPF



Conversion factors

η_par: Percentage of spectral power inside the PAR region

η_par
0,99

η_photon: Conversion factor, units: µmol/s/W*

η_photon
4,42

η_v: Conversion factor, units: lm/W*

η_v
280,87

The conversion between energy-based PAR and photon-based PAR depends on the spectrum of the light source (see Photosynthetic efficiency). The following table shows the conversion factors from watts for black-body spectra that are truncated to the range 400–700 nm. It also shows the luminous efficacy for these light sources and the fraction of a real black-body radiator that is emitted as PAR.

T (K)	η_v (lm/W*)	η_{photon} (µmol/J* or µmol $s^{-1}W^{*-1}$)	η_{photon} (mol day^{-1} W^{*-1})	η_{PAR} (W*/W)
3000 (warm white)	269	4.98	0.43	0.0809
4000	277	4.78	0.413	0.208
5800 (daylight)	265	4.56	0.394	0.368
Note: W* and J* indicates PAR watts and PAR joules (400–700 nm).				

For example, a light source of 1000 lm at a color temperature of 5800 K would emit approximately 1000/265 = 3.8 W of PAR, which is equivalent to 3.8*4.56 = 17.3 µmol/s. For a black-body light source at 5800 K, such as the sun is approximately, a fraction 0.368 of its total emitted radiation is emitted as PAR. For artificial light sources, that usually do not have a black-body spectrum, these conversion factors are only approximate.

The quantities in the table are calculated as

$$\eta_v(T) = \frac{\int_{\lambda_1}^{\lambda_2} B(\lambda,T)\, 683\, [\mathrm{lm/W}]\, y(\lambda)\, d\lambda}{\int_{\lambda_1}^{\lambda_2} B(\lambda,T)\, d\lambda},$$

$$\eta_{\mathrm{photon}}(T) = \frac{\int_{\lambda_1}^{\lambda_2} B(\lambda,T)\, \frac{\lambda}{hcN_A}\, d\lambda}{\int_{\lambda_1}^{\lambda_2} B(\lambda,T)\, d\lambda},$$

$$\eta_{\mathrm{PAR}}(T) = \frac{\int_{\lambda_1}^{\lambda_2} B(\lambda,T)\, d\lambda}{\int_0^{\infty} B(\lambda,T)\, d\lambda},$$

where $B(\lambda,T)$ is the black-body spectrum according to Planck's law, y is the standard luminosity function, λ_1, λ_2 represent the wavelength range (400 700 nm) of PAR, and N_A is the Avogadro constant.

*Please see: https://en.wikipedia.org/wiki/Photosynthetically_active_radiation

Glossary of important terms related to horticultural lighting

PPFD Total Par Zone (400-700nm): Numer of photons within a specific rangeï¼ˆfrom 400- 700 nm for plant growth) of the visible light spectrum (photosynthetic a ctive radiation or PAR) that fall on a square meter of target area per second. The unit is Âµmol/mÂ²s. Intensity mainly affects the overall yield of your crop. In general, the minimum PPFD value needed for plant growth is 53 Âµmol/mÂ²s. For more info: https://en.wikipedia.org/wiki/Photosynthetically_active_radiation

PPFD NIR Zone (700-800nm): Far red Photosynthetic photon flux density in the range of 700-800 nm.

PPFD Red Zone (600-700nm): Photosynthetic photon flux density in the range of 600 to 700 nm.

PPFD Green Zone (500-600nm): Photosynthetic photon flux density in the range of 500 to 600 nm.

PPFD Blue Zone (400-500nm): Photosynthetic photon flux density in the range of 400 to 500 nm.

PPFD UV Zone (350-400nm): UV-A Photosynthetic photon flux density in the range of 350-400 nm

YPFD Total Par Zone (400-700nm): PPFD is just calculated from a known spectrum and not related to the plant light response itself. In order to estimate howefficient a given light is for plants, we need to weight PPFD values with the PAR action spectrum (400 nm to 700 nm) to get Yield Photon Flux Density (YPFD). Of course, YPFD will change when the reference PAR action spectrum changes

YPFD IR Zone (700-800nm): Weights the spectral characteristics of photons with the PAR action spectrum in the far red range

YPFD Red Zone (600-700nm): Weights the spectral characteristics of photons with the PAR action spectrum in the 600 to 700 nm range

YPFD Green Zone (500-600nm): Weights the spectral characteristics of photons with the PAR action spectrum in the 500 to 600 nm range

YPFD Blue Zone (360-500nm): Weights the spectral characteristics of photons with the PAR action spectrum in the 360 to 500 nm range

YPFD UV Zone (350-400nm): Weights the spectral characteristics of photons with the PAR action spectrum in the UV-A zone

Red/Blue ratio: R/B is the ration bwtween PPFD Red Zone (600-700nm) and the PPFD Blue Zone (400-500nm). Indicates the effects on the growth productivity related to stem elongation and leaf expansion. Blue light has significant effects on the morphology of plants aside from Photo-synthesis.

Red/Far-red ratio: R/FR ratio between the PPFD Red Zone (600-700nm) and the PPFD NIR Zone (700-800nm). Indicates the effects on the growth productivity related to flowering, setting winter buds and vegetative growth.

Daily Light Integral (DLI): Is the aggregated amount of PAR light that a surface receives over the course of a day. It is a very useful metric to determine if a particular location receives sufficient amounts of light for plants to grow well. Low light plants require between 5-10 mol/mÂ²/day, medium light plants 10-15 mol/mÂ²/day, and high light plants will require more than 15 mol/mÂ²/day. More info: https://en.wikipedia.org/wiki/Daily_light_integral

Î·_par: Conversion factor. Percentage of spectral power inside the PAR region. More info: https://en.wikipedia.org/wiki/Photosynthetically_active_radiation

Î·_photon: Conversion factor. From W/mÂ² to Âµmol/s/mÂ². More info: https://en.wikipedia.org/wiki/Photosynthetically_active_radiation

Î·_v: Conversion factor. From W/mÂ² to lx. More info: https://en.wikipedia.org/wiki/Photosynthetically_active_radiation

Effective Irradiance (Edm)	
Edm [W/m²]	0,67
Damage potential (Pdm)	
Pdm [mW/lm]	0,33
Threshold exposure (ts)	
ts [hours]	1267
Illuminance (E)	
Illuminance [lx]	2.031,37

0,05	340000	113334	56667	34000	17000	8500	3400	850
0,10	170000	56667	28334	17000	8500	4250	1700	425
0,11	154546	51516	25758	15455	7728	3864	1546	387
0,12	141667	47223	23612	14167	7084	3542	1417	355
0,13	130770	43590	21795	13077	6539	3270	1308	327
0,14	121429	40477	20239	12143	6072	3036	1215	304
0,15	113334	37778	18889	11334	5667	2834	1134	284
0,16	106250	35417	17709	10625	5313	2657	1063	266
0,17	100000	33334	16667	10000	5000	2500	1000	250
0,18	94445	31482	15741	9445	4723	2362	945	237
0,20	85000	28334	14167	8500	4250	2125	850	213
0,23	73914	24638	12319	7392	3696	1848	740	185
0,27	62963	20988	10494	6297	3149	1575	630	158
0,54	31482	10494	5247	3149	1575	788	315	79

Material: TEXTILE MATERIALS. Effective Irradiance, Potential damage and Threshold Exposure time

Textile materials

Textile materials	
Effective Irradiance (Edm)	
Edm [W/m²]	0,89
Damage potential (Pdm)	
Pdm [mW/lm]	0,44
Threshold exposure (ts)	
ts [hours]	325
Illuminance (E)	
Illuminance [lx]	2.031,37

				Illuminance [lx]				
	50	150	300	500	1000	2000	5000	20000
Pdm [mW/lm]				Threshold exposure [hours]				
0,01	580000	193334	96667	58000	29000	14500	5800	1450
0,05	116000	38667	19334	11600	5800	2900	1160	290
0,10	58000	19334	9667	5800	2900	1450	580	145
0,11	52728	17576	8788	5273	2637	1319	528	132
0,12	48334	16112	8056	4834	2417	1209	484	121
0,13	44616	14872	7436	4462	2231	1116	447	112
0,14	41429	13810	6905	4143	2072	1036	415	104
0,15	38667	12889	6445	3867	1934	967	387	97
0,16	36250	12084	6042	3625	1813	907	363	91
0,17	34118	11373	5687	3412	1706	853	342	86
0,18	32223	10741	5371	3223	1612	806	323	81
0,20	29000	9667	4834	2900	1450	725	290	73
0,23	25218	8406	4203	2522	1261	631	253	64
0,27	21482	7161	3581	2149	1075	538	215	54
0,54	10741	3581	1791	1075	538	269	108	27

Material: WATER COLORS. Effective Irradiance, Potential damage and Threshold Exposure time

Water colors

Water colors	
Effective Irradiance (Edm)	
Edm [W/m²]	0,67
Damage potential (Pdm)	
Pdm [mW/lm]	0,33
Threshold exposure (ts)	
ts [hours]	261
Illuminance (E)	
Illuminance [lx]	2.031,37

				Illuminance [lx]				
	50	150	300	500	1000	2000	5000	20000
Pdm [mW/lm]				Threshold exposure [hours]				
0,01	350000	116667	58334	35000	17500	8750	3500	875
0,05	70000	23334	11667	7000	3500	1750	700	175
0,10	35000	11667	5834	3500	1750	875	350	88
0,11	31819	10607	5304	3182	1591	796	319	80
0,12	29167	9723	4862	2917	1459	730	292	73
0,13	26924	8975	4488	2693	1347	674	270	68
0,14	25000	8334	4167	2500	1250	625	250	63
0,15	23334	7778	3889	2334	1167	584	234	59
0,16	21875	7292	3646	2188	1094	547	219	55
0,17	20589	6863	3432	2059	1030	515	206	52
0,18	19445	6482	3241	1945	973	487	195	49
0,20	17500	5834	2917	1750	875	438	175	44
0,23	15218	5073	2537	1522	761	381	153	39
0,27	12963	4321	2161	1297	649	325	130	33
0,54	6482	2161	1081	649	325	163	65	17

Glossary of important terms related to damage of materials by optical radiation

CIE damage functions sdf(Î»): Damage function curves for materials which follow an exponential decay with the increase of wavelength. These functions depend on the type of material (water colors, oil paint, paper, textile materials, etc). More info: http://cie.co.at/publications/control-damage-museum-objects-optical-radiation

Potential damage: Typically expressed in mW/lm, evaluates the damage generated by a light spectrum on a given material under a certain exposu re, in which the illuminance in lux, exposure time t and Spectral Power Distribution are known. The thermal effect of infrared in the light source dry, deform and crack the materials. The UV radiation is a chemical effect, which will cause the fading and discoloration of the material. More info: http://cie.co.at/publications/control-damage-museum-objects-optical-radiation