International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

User Guide to the α -opic Toolbox for implementing CIE S 026

This User Guide relates to the α -opic Toolbox v1.049a, published by CIE Division 6.
The Toolbox (DOI 10.25039/S026.2018.TB) and User Guide (DOI 10.25039/S026.2018.UG) are
maintained under CIE Division Reportership (DR) 6-45.

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Toolbox – Basis, disclaimer and contact

The α -opic Toolbox and User Guide were designed by the International Commission on Illumination (CIE) to enable calculations and conversions of quantities related to ipRGC-influenced responses to light (IIL responses, or non-visual effects of light), following the international standard *CIE S 026:2018. System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light*. CIE, Vienna ([DOI: 10.25039/S026.2018](https://doi.org/10.25039/S026.2018)).

The α -opic Toolbox is a CIE publication ([DOI: 10.25039/S026.2018.TB](https://doi.org/10.25039/S026.2018.TB)) under the Division 6 Reportership DR 6-45 *Publication and maintenance of the CIE S 026 Toolbox*. The α -opic Toolbox supports the usage of CIE S 026, but is not part of the official international standard. The toolbox was designed with feedback from experts including the participants of the *Tutorial on CIE S 026. Use and application of the new metrology for ipRGC-influenced responses to light*, 14-15 March 2019, Eindhoven.

No liability is taken by CIE for any potential errors due to calculations with the α -opic Toolbox. It is recommended that users check the results against manual calculations. Considered feedback is welcome and should be sent to the Reporter of DR 6-45 via ciecb@cie.co.at who will aim to answer any questions as quickly as possible.

Toolbox – Author and advisors

- The following member of DR 6-45 took part in the preparation of the Toolbox and this User Guide
 - Price, L.L.A. Public Health England, United Kingdom
- The following experts acted as advisors:
 - Peirson, S.N. University of Oxford, United Kingdom
 - Schlangen, L.J.M. Eindhoven University of Technology, The Netherlands
 - Spitschan, M. University of Oxford, United Kingdom
 - Lang, D. LEDVANCE, Munich, Germany
 - Blattner, P. METAS, Bern, Switzerland

Toolbox – Main features

- Selection of spectral data used for calculations

Built-in illuminants A, D65, E, FL11, and LED-B3 (all: range 380 nm to 780 nm, step 1 nm) (CIE, 2018a); or User-defined spectral data with a choice of wavelength step (1 nm, 2 nm, 4 nm or 5 nm)

- Choice of basic quantity

Photon radiance, photon irradiance, radiance, irradiance, luminance, illuminance (CIE, 2011; BIPM, 2019)
Control of SI prefixes, e.g. **m** in $\text{mW}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}$, μ and **c** in $\mu\text{W}\cdot\text{cm}^{-2}$, **k** in klx , **c** in $\text{cd}\cdot\text{cm}^{-2}$

- CIE S 026 calculations and conversions (CIE, 2018b)

Basic quantity and additional α -opic output quantities are calculated: α -opic irradiance, α -opic equivalent daylight (D65) illuminance (α -opic EDI), α -opic photon irradiance, or their radiance and luminance analogues, as well as the α -opic efficacy of luminous radiation (α -opic ELR)

Toolbox – Additional features

- Charts and action spectra

The test spectrum and the reference spectrum (default = D65) before and after α -opic action spectra weighting

- Glossary

List of quantities, abbreviations and symbols from CIE S 026 (CIE, 2018b)

- Advanced outputs

Switch outputs between the quantities from CIE S 026 and the former Lucas *et al.*, 2014 recommendations

Displays values for the reference source, matched to the test source inputs

Displays α -opic Daylight Efficacy Ratio (α -opic DER)

Control of SI prefixes

Inputs – Quick calculations

Example for built-in spectra

First enter a title

< Quick calculation >

1. Select from list

(5 CIE illuminants) < LED-B3 >

2. Select quantity

(6 options) < illuminance >

and units

(SI prefixes) < k > < blank >

3. Enter value

(0.10 klx = 100 lx) < 0.10 >

Finally clear unused inputs

(i.e. manually clear cells C24:C424)

CIE S 026 α -opic Toolbox

Inputs sheet Inputs = blue

Quick calculation

1. Select source of spectral data
Spectrum LED-B3
LED-B3: Range 380 nm to 780 nm, step 1 nm

2. Select measurement details
Quantity, Q illuminance
Main SI prefix k
Clear this input

3. Enter illuminance value
Enter value 0.10 klx

LED-B3

User
A
D65
E
FL11
LED-B3

illuminance

photon radiance
photon irradiance
radiance
irradiance
luminance
illuminance

k

E
P
T
G
M
k
m
 μ
n
p
f
a

c
m
 μ

All of A, D65, E, FL11, LED-B3 have a range 380 nm to 780 nm, and step 1 nm

Inputs – Dealing with Error Messages

- Check whether there is red text under ‘Error messages’.
- In case of (red) error messages, follow instructions relating to the input/cell (usually highlighted with a red asterisk).
- If not, please go to the next page of the User Guide (Output Results).

NOTE Use a comma or a dot as your decimal separator based on your Excel settings.

Outputs – What results are provided?

Basic quantities

irradiance, illuminance and log photon irradiance

α -opic irradiance

(in $\text{W}\cdot\text{m}^{-2}$)

α -opic ELR

efficacy of luminous radiation, (in $\text{mW}\cdot\text{lm}^{-1}$)

α -opic EDI

equivalent daylight (D65) illuminance, (in lx)

α -opic photon irradiance

(in $\text{s}^{-1}\cdot\text{m}^{-2}$)

Each value is presented as the logarithm to base 10 ($\log_{10}$) of the α -opic photon irradiance, Q , divided by $1 \text{ s}^{-1}\cdot\text{m}^{-2}$ ($\log_{10}$ can also be written lg).

$(\text{unweighted}) \text{ irradiance} = \int \text{spectral irradiance} * d\lambda$
 $(\text{photopic}) \text{ illuminance} = K_m * \int \text{spectral irradiance} * V(\lambda) * d\lambda$, where $K_m \approx 683 \text{ lm.W}^{-1}$
 $(\text{unweighted}) \text{ photon irradiance} = \int \text{spectral photon irradiance} * d\lambda$

irradiance, W.m-2	illuminance, lx	log photon irradiance/(s-1.m-2)		
0.32	100.00	17.953		
α -opic irradiance, W.m-2 α -opic irradiance = $\int \text{spectral irradiance} * \alpha$ -opic action spectrum * $d\lambda$				
α -opic irradiance α -opic irradiance = $\int \text{spectral irradiance} * \alpha$ -opic action spectrum * $d\lambda$				
S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.05	0.13	0.16	0.10	0.08
α -opic efficacy of luminous radiation, mW.lm-1 α -opic ELR = α -opic irradiance / illuminance			α -opic ELR	
S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.5057	1.2870	1.6253	1.0126	0.8387
α -opic equivalent daylight (D65) illuminance, lx α -opic EDI = α -opic irradiance / α -opic ELR for daylight (D65)			α -opic EDI	
S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
61.88	88.40	99.78	69.85	63.24
$\log \alpha$ -opic photon irradiance, log Q/(s-1.m-2), where α -opic photon irradiance = $\int \text{spectral photon irradiance} * \alpha$ -opic action spectrum * $d\lambda$			α -opic photon irradiance	
S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
17.057	17.544	17.666	17.411	17.315

Outputs – Basic quantities

irradiance

(in $\text{W}\cdot\text{m}^{-2}$)

illuminance

(in lx)

photon irradiance

(in $\text{s}^{-1}\cdot\text{m}^{-2}$ and presented as a logarithm)

$$(\text{unweighted}) \text{ irradiance} = \int \text{spectral irradiance} \cdot d\lambda$$

$$(\text{photopic}) \text{ illuminance} = K_m \cdot \int \text{spectral irradiance} \cdot V(\lambda) \cdot d\lambda, \text{ where } K_m \approx 683 \text{ lm}\cdot\text{W}^{-1}$$

$$(\text{unweighted}) \text{ photon irradiance} = \int \text{spectral photon irradiance} \cdot d\lambda$$

irradiance, $\text{W}\cdot\text{m}^{-2}$

0.32

illuminance, lx

100.00

log photon irradiance/($\text{s}\cdot\text{m}^{-2}$)

17.953

Outputs – α -opic irradiance

$$E_{\alpha} \text{ (in } \text{W}\cdot\text{m}^{-2}\text{)}$$

"effective photobiological irradiance with the spectral irradiance, $E_{e,\lambda}(\lambda)$, spectrally weighted with the α -opic action spectrum $s_{\alpha}(\lambda)$ "

(unweighted) irradiance = $\int \text{spectral irradiance} * d\lambda$
 (photopic) illuminance = $K_m * \int \text{spectral irradiance} * V(\lambda) * d\lambda$, where $K_m = 683 \text{ lm}\cdot\text{W}^{-1}$
 (unweighted) photon irradiance = $\int \text{spectral photon irradiance} * d\lambda$

irradiance, $\text{W}\cdot\text{m}^{-2}$	illuminance, lx	log photon irradiance/(s-1.m-2)
0.32	100.00	17.953

α -opic irradiance, $\text{W}\cdot\text{m}^{-2}$
 α -opic irradiance = $\int \text{spectral irradiance} * \alpha$ -opic action spectrum * $d\lambda$

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.05	0.13	0.16	0.10	0.08

α -opic efficacy of luminous radiation, $\text{mW}\cdot\text{lm}^{-1}$
 α -opic ELR = α -opic irradiance / illuminance

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.5057	1.2870	1.6253	1.0126	0.8387

α -opic equivalent daylight (D65) illuminance, lx
 α -opic EDI = α -opic irradiance / α -opic ELR for daylight (D65)

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
61.88	88.40	99.78	69.85	63.24

log α -opic photon irradiance, $\log Q/(\text{s}\cdot\text{1}\cdot\text{m}\cdot\text{2})$, where
 α -opic photon irradiance = $\int \text{spectral photon irradiance} * \text{photon system } \alpha$ -opic action spectrum * $d\lambda$

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
17.057	17.544	17.666	17.411	17.315

α -opic irradiance, $\text{W}\cdot\text{m}^{-2}$

$$\alpha\text{-opic irradiance} = \int \text{spectral irradiance} * \alpha\text{-opic action spectrum} * d\lambda$$

α -opic irradiance

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.05	0.13	0.16	0.10	0.08

Example calculation – Melanopic irradiance

Outputs – α -opic ELR

ELR = Efficacy of
Luminous
Radiation

$$K_{\alpha,v} = E_{\alpha} / E_v$$

E_v

E_{α}

α -opic efficacy of luminous radiation, mW.lm⁻¹

α -opic ELR

α -opic ELR = α -opic irradiance / illuminance

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.5057	1.2870	1.6253	1.0126	0.8387

EDI = Equivalent
Daylight (D65)
Illuminance

"illuminance, produced by radiation conforming to standard daylight (D65), that provides an equal α -opic irradiance as the test source"

$(\text{unweighted}) \text{ irradiance} = \int \text{spectral irradiance} \cdot d\lambda$
 $(\text{photopic}) \text{ illuminance} = K_m \cdot \int \text{spectral irradiance} \cdot V(\lambda) \cdot d\lambda$, where $K_m = 683 \text{ lm} \cdot \text{W}^{-1}$
 $(\text{unweighted}) \text{ photon irradiance} = \int \text{spectral photon irradiance} \cdot d\lambda$

irradiance, W.m ⁻²	illuminance, lx	log photon irradiance/(s ⁻¹ .m ⁻²)
0.32	100.00	17.953
α -opic irradiance		
α -opic irradiance = $\int \text{spectral irradiance} \cdot \alpha$ -opic action spectrum $\cdot d\lambda$		
S-cone-opic	M-cone-opic	L-cone-opic
0.05	0.13	0.16
Rhodopic	Melanopic	
0.10	0.08	
α -opic efficacy of luminous radiation, mW.lm ⁻¹		
α -opic ELR = α -opic irradiance / illuminance		
S-cone-opic	M-cone-opic	L-cone-opic
0.5057	1.2870	1.6253
Rhodopic	Melanopic	
1.0126	0.8387	
α -opic equivalent daylight (D65) illuminance, lx		
α -opic EDI = α -opic irradiance / α -opic ELR for daylight (D65)		
S-cone-opic	M-cone-opic	L-cone-opic
61.88	88.40	99.78
Rhodopic	Melanopic	
69.85	63.24	
log α -opic photon irradiance, log Q/(s ⁻¹ .m ⁻²), where		
α -opic photon irradiance = $\int \text{spectral photon irradiance} \cdot \alpha$ -opic action spectrum $\cdot d\lambda$		
S-cone-opic	M-cone-opic	L-cone-opic
17.057	17.544	17.666
Rhodopic	Melanopic	
17.411	17.315	

α -opic equivalent daylight (D65) illuminance, lx

α -opic EDI = α -opic irradiance / α -opic ELR for daylight (D65)

α -opic EDI

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
61.88	88.40	99.78	69.85	63.24

Outputs – α -opic EDI calculation method

EDI = Equivalent
Daylight (D65)
Illuminance

$$E_{v,\alpha}^{D65} = E_{\alpha} / K_{\alpha,v}^{D65}$$

since $K_{\alpha,v} = E_{\alpha} / E_v$

$K_{\alpha,v}^{D65}$ are five fixed values

"illuminance, produced by radiation conforming to standard daylight (D65), that provides an equal α -opic irradiance as the test source"

α -opic equivalent daylight (D65) illuminance, lx

α -opic EDI = α -opic irradiance / α -opic ELR for daylight (D65)

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
61.88	88.40	99.78	69.85	63.24

S-cone-opic	0.8173	mW.lm-1
M-cone-opic	1.4558	mW.lm-1
L-cone-opic	1.6289	mW.lm-1
Rhodopic	1.4497	mW.lm-1
Melanopic	1.3262	mW.lm-1

Example calculation – Melanopic equivalent daylight (D65) illuminance

$$\div 1.326 = 63.2 \text{ lx}$$

as shown on p. 15

= melanopic EDI

Example calculations – Summary

melanopic
irradiance

÷

melanopic
ELR

=

melanopic
EDI

83.9 mW·m⁻²

÷

1.326 mW·lm⁻¹

=

63.2 lx

1 mW·m⁻²

÷

1 mW·lm⁻¹

=

1 lm·m⁻²

=

1 lx

Outputs – α -opic photon irradiance

$$E_{p,\alpha} \text{ (in } s^{-1} \cdot m^{-2} \text{)}$$

"effective photobiological photon irradiance with the spectral photon irradiance, $E_{p,\lambda}(\lambda)$ (or number of photons per second per square metre), spectrally weighted with the α -opic action spectrum $s_{p,\alpha}(\lambda)$ "

Each value is presented as the logarithm to base 10 ($\log_{10}$) of the α -opic photon irradiance, Q , divided by $1 s^{-1} \cdot m^{-2}$.

log α -opic photon irradiance, log Q/(s-1.m-2), where

α -opic photon irradiance = $\int$ spectral photon irradiance * photon system α -opic action spectrum * $d\lambda$

α -opic photon irradiance

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
17.057	17.544	17.666	17.411	17.315

Photon irradiance in standard notation

$$\begin{aligned} \text{(unweighted) irradiance} &= \int \text{spectral irradiance} * d\lambda \\ \text{(photopic) illuminance} &= K_m * \int \text{spectral irradiance} * V(\lambda) * d\lambda, \text{ where } K_m \approx 683 \text{ lm.W}^{-1} \\ \text{(unweighted) photon irradiance} &= \int \text{spectral photon irradiance} * d\lambda \end{aligned}$$

irradiance, W.m-2

0.32

illuminance, lx

100.00

log photon irradiance/(s-1.m-2)

17.953

log α -opic photon irradiance, log Q/(s-1.m-2), where

$$\alpha\text{-opic photon irradiance} = \int \text{spectral photon irradiance} * \text{photon system } \alpha\text{-opic action spectrum} * d\lambda$$

α -opic photon irradiance

S-cone-opic

M-cone-opic

L-cone-opic

Rhodopic

Melanopic

17.057

17.544

17.666

17.411

17.315

α -opic photon irradiance in standard notation

e.g. $2.065\text{E}+17 = 10^{17.315}$, with rounding to 3 decimal places

photon irradiance, s-1.m-2

8.969E+17

α -opic photon irradiance, s-1.m-2

1.139E+17

3.503E+17

4.638E+17

2.578E+17

2.065E+17

Inputs – User-defined spectrum (1)

Example for user spectra

First enter a title

< User defined spectrum 001 >

1. Select 'User' from list

< User >

2. Select spectral quantity

(4 options*) < irradiance >

and units

(SI prefixes) < μ > < c >

* luminance and illuminance are not supported as spectral inputs

Inputs – User-defined spectrum (2)

2. Select spectral quantity

(4 options)

< irradiance >

and units

(SI prefixes)

< μ > < c >

3. Clear this input

4. Enter resolution

(1 nm, 2 nm, 4 nm or 5 nm)

< 2 >

5. Enter spectral data

(380 nm to 780 nm)

Finally clear any data below the row for 780 nm.

2. Select measurement details

Spectral quantity, Q
Main SI prefix
Area prefix

irradiance
 μ
c

3. Skip this step

Clear this input

4. Select wavelength step

Step size, nm

2

5. Enter spectral irradiance data

nm	$\mu\text{W.cm}^{-2}.\text{nm}^{-1}$
380	1.000
382	1.000
384	1.000
386	1.000
388	1.000
390	1.000
392	1.000

The spectral quantity, units and the resolution of the spectral data in step 5 depend on steps 2 and 4, as indicated by the arrows.

Charts – Spectra and α -opic weightings

The input data is called the Test source. The default CIE S 026 Reference source is daylight (D65); Lucas et al., 2014 uses equi-energy (E).

The units used on the y-axis depend on the prefixes selected in Inputs cells C12 and C13. The units used in the chart titles depend on the prefixes selected in Advanced Outputs cells H10 and H11.

List of quantities, abbreviations and symbols

Previously published (CIE DIS 017:2016; CIE 018:2019)

E_v = (photopic) illuminance; L_v = (photopic) luminance

$E = E_e$ = irradiance (*i.e.* unweighted); $L = L_e$ = radiance (*i.e.* unweighted)

E_p = photon irradiance (*i.e.* unweighted); L_p = photon radiance (*i.e.* unweighted)

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)

$s_\alpha(\lambda) = s_{e,\alpha}(\lambda) = \alpha$ -opic spectral weighting function (action spectrum)

$K_{\alpha,v} = \alpha$ -opic efficacy of luminous radiation, **α -opic ELR**

$K_{\alpha,v}^{D65} = \alpha$ -opic ELR for daylight (D65)

$\gamma_{\alpha,v}^{D65} = \alpha$ -opic daylight (D65) efficacy ratio, **α -opic DER**

$E_\alpha = E_{e,\alpha} = \alpha$ -opic irradiance (*i.e.* weighted by $s_\alpha(\lambda)$)

$E_{v,\alpha}^{D65} = \alpha$ -opic equivalent daylight (D65) illuminance, **α -opic EDI**

$L_\alpha = L_{e,\alpha} = \alpha$ -opic radiance (*i.e.* weighted by $s_\alpha(\lambda)$)

$L_{v,\alpha}^{D65} = \alpha$ -opic equivalent daylight (D65) luminance, **α -opic EDL**

From CIE S 026:2018 and 9th edition of SI Brochure

$s_{p,\alpha}(\lambda) = \alpha$ -opic spectral weighting function (action spectrum) in the photon system (renormalised to maximum of 1)

$E_{p,\alpha} = \alpha$ -opic photon irradiance (*i.e.* weighted by $s_{p,\alpha}(\lambda)$)

$L_{p,\alpha} = \alpha$ -opic photon radiance (*i.e.* weighted by $s_{p,\alpha}(\lambda)$)

Further α -opic quantities and their symbols can be derived, *e.g.* α -opic equivalent daylight (D65) luminous flux, $\Phi_{v,\alpha}^{D65}$. However, any other abbreviations, *e.g.* " α -opic EDLF" may be ambiguous, and should be avoided.

Due to prior publications, the subscript order for ELR and DER differs from α -opic equivalent daylight (D65) quantities.

Advanced Outputs – Output mode selection

CIE S 026 α-opic Toolbox

Select current "CIE S 026" or old "Lucas et al., 2014" quantities: **CIE S 026**

Advanced Outputs Please note the α-opic Toolbox is not part of CIE S 026. See Disclaimer sheet.

Inputs = blue

Inputs: Basis of system: **radiant flux (power), W** Quantity: **radiance** Units: **μW.cm-2** Select: **μ** Do not use: **W** **1E+00** **1E-02**

Outputs: **luminous flux, lm** **illuminance, lx** **photon flux, s-1** **photon irradiance, log Q/(s-1.cm-2)**

Output prefix: **μ** Area prefix: **c** Scaling factors: **1E-02**

Inputs: Standard CIE S 026 calculations. Note to (T2) $K_m = K_{ap} = 683 \text{ lm W}^{-1}$

Values for: **radiance, μW.cm-2** **illuminance, lx** **log photon irradiance/(s-1.cm-2)**

User defined spectrum 001: 401.00 729.83 15.069
daylight (D65): 356.32 729.83 15.007

α-opic irradiance, μW.cm-2 α-opic irradiance = ∫ spectral irradiance * α-opic action spectrum * dλ (T1) (T2) (T3)

α-opic irradiance for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 55.20 101.94 119.61 97.07 87.68
daylight (D65): 59.65 106.25 118.88 105.80 96.79

α-opic efficacy of luminous radiation, mW.lm-1 α-opic ELR = α-opic irradiance / illuminance (T4) (T5)

α-opic ELR for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 0.7564 1.3968 1.8389 1.3301 1.2013
daylight (D65): 0.8173 1.4558 1.8299 1.4497 1.3262

α-opic daylight (D65) efficacy ratio, 1 α-opic DER = α-opic ELR / α-opic ELR for daylight (D65) (T6)

α-opic EDI for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 9.9255 0.9394 1.0061 9.9175 9.9058
daylight (D65): 1.0000 1.0000 1.0000 1.0000 1.0000

α-opic equivalent daylight (D65) illuminance, lx α-opic EDI = α-opic irradiance / α-opic ELR for daylight (D65) α-opic EDI = illuminance * α-opic DER (T7) (T8)

α-opic EDI for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 675.46 700.22 734.31 669.59 668.10
daylight (D65): 729.83 729.83 729.83 729.83 729.83

log α-opic photon irradiance, log Q/(s-1.cm-2), where α-opic photon irradiance = ∫ spectral photon irradiance * photon system α-opic action spectrum * dλ (T9)

α-opic photon irradiance for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 14.095 14.443 14.533 14.393 14.334
daylight (D65): 14.128 14.461 14.531 14.430 14.377

CIE S 026 α-opic Toolbox

Select current "CIE S 026" or old "Lucas et al., 2014" quantities: **Lucas et al., 2014**

Advanced Outputs Please note the α-opic Toolbox is not part of CIE S 026. See Disclaimer sheet.

Inputs = blue

Inputs: Basis of system: **radiant flux (power), W** Quantity: **radiance** Units: **μW.cm-2** Select: **μ** Do not use: **W** **1E+00** **1E-02**

Outputs: **luminous flux, lm** **illuminance, lx** **photon flux, s-1** **photon irradiance, log Q/(s-1.cm-2)**

Output prefix: **μ** Area prefix: **c** Scaling factors: **1E-02**

Inputs: Standard CIE S 026 calculations. Note to (T2) $K_m = K_{ap} = 683 \text{ lm W}^{-1}$

Values for: **radiance, μW.cm-2** **illuminance, lx** **log photon irradiance/(s-1.cm-2)**

User defined spectrum 001: 401.00 729.83 15.069
daylight (D65): 356.32 729.83 15.007

α-opic irradiance, μW.cm-2 α-opic irradiance = ∫ spectral irradiance * α-opic action spectrum * dλ (T1) (T2) (T3)

α-opic irradiance for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 54.94 117.68 126.04 103.42 87.68
daylight (D65): 59.65 106.25 118.88 105.80 96.79

α-opic efficacy of luminous radiation, mW.lm-1 α-opic ELR = α-opic irradiance / illuminance (T4) (T5)

α-opic ELR for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 0.7527 1.6124 1.7269 1.4121 1.2097
daylight (D65): 0.8173 1.4558 1.8299 1.4497 1.3262

α-opic daylight (D65) efficacy ratio, 1 α-opic DER = α-opic ELR / α-opic ELR for daylight (D65) (T6)

α-opic EDI for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 1.0000 1.0000 1.0000 1.0000 1.0000
daylight (D65): 1.0000 1.0000 1.0000 1.0000 1.0000

α-opic equivalent daylight (D65) illuminance, lx α-opic EDI = α-opic irradiance / α-opic ELR for daylight (D65) α-opic EDI = illuminance * α-opic DER (T7) (T8)

α-opic EDI for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 729.83 729.83 729.83 729.83 729.83
daylight (D65): 729.83 729.83 729.83 729.83 729.83

log α-opic photon irradiance, log Q/(s-1.cm-2), where α-opic photon irradiance = ∫ spectral photon irradiance * photon system α-opic action spectrum * dλ (T9)

α-opic photon irradiance for: **S-cone-opic** **M-cone-opic** **L-cone-opic** **Rhodopic** **Melanopic**

User defined spectrum 001: 14.085 14.508 14.558 14.424 14.334
daylight (D65): 14.085 14.508 14.558 14.424 14.334

"Lucas et al., 2014" mode
Provided for checking
old calculations only

Reverts to non-standard terminology

Advanced Outputs – Daylight efficacy ratio (DER)

“ α -opic daylight (D65) efficacy ratio, <for a source>”

$$\gamma_{\alpha,v}^{D65} \quad \text{where} \quad \gamma_{\alpha,v}^{D65} = K_{\alpha,v} / K_{\alpha,v}^{D65}$$

Converts illuminance, E_v , to α -opic EDI:

$$E_{v,\alpha}^{D65} = E_v \cdot \gamma_{\alpha,v}^{D65}$$

INPUTS: Standard CIE S 026 calculations.
Note to (T2) $E_v = E_{D65} = 483 \text{ lm W}^{-1}$

(unweighted) irradiance = $\int \text{spectral irradiance} \cdot d\lambda$ (T1)
(photopic) illuminance = $K_e \cdot \int \text{spectral irradiance} \cdot V(\lambda) \cdot d\lambda$ (T2)
(unweighted) photon irradiance = $\int \text{spectral photon irradiance} \cdot d\lambda$ (T3)

Values for

User defined spectrum 001 daylight (D65)	Test source Reference: "0"	irradiance, $\mu\text{W cm}^{-2}$ 401.00 356.33	photon irradiance, $10^{17} \text{ photons m}^{-2} \text{ s}^{-1}$ 729.83 729.83	log photon irradiance/(s-1.cm-2) 15.069 15.007
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α -opic irradiance, $\mu\text{W cm}^{-2}$
 α -opic irradiance = $\int \text{spectral irradiance} \cdot \alpha \cdot \text{action spectrum} \cdot d\lambda$ (T4)

	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
User defined spectrum 001 daylight (D65)	35.20 59.65	101.94 106.25	119.61 118.88	97.07 105.80	87.68 96.79

α -opic efficacy of luminous radiation, mW lm^{-1}
 α -opic ELR = α -opic irradiance / illuminance (T5)

	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
User defined spectrum 001 daylight (D65)	0.7564 0.8173	1.3968 1.4358	1.6389 1.6289	1.3301 1.4497	1.2013 1.3262

α -opic daylight (D65) efficacy ratio, 1
 α -opic DER = α -opic ELR / α -opic ELR for daylight (D65) (T6)

	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
User defined spectrum 001 daylight (D65)	0.9255 1.0000	0.9594 1.0000	1.0061 1.0000	0.9175 1.0000	0.9058 1.0000

α -opic equivalent daylight (D65) illuminance, lx
 α -opic EDI = α -opic irradiance / α -opic ELR for daylight (D65) (T7)
 α -opic EDI = illuminance * α -opic DER (T8)

	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
User defined spectrum 001 daylight (D65)	675.46 729.83	700.22 729.83	734.31 729.83	669.59 729.83	661.10 729.83

log α -opic photon irradiance, log Q/(s-1.cm-2), where
 α -opic photon irradiance = $\int \text{spectral photon irradiance} \cdot \alpha \cdot \text{action spectrum} \cdot d\lambda$ (T9)

α -opic daylight (D65) efficacy ratio, 1

α -opic DER = α -opic ELR / α -opic ELR for daylight (D65)

α -opic DER

α -opic DER for

		S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
User defined spectrum 001 daylight (D65)		0.9256	0.9594	1.0061	0.9175	0.9058
		1.0000	1.0000	1.0000	1.0000	1.0000

Advanced Outputs – Reference source values

Reference source values are shown matched to the input for the test source

Reference source (automatic) =

Daylight (D65) for CIE S 026 mode

Equi-energy (E) for Lucas et al., 2014 mode

INPUTS: Standard CIE S 026 calculations.
Note to (T2) $K_{cd} = K_{cd} = 683 \text{ lm W}^{-1}$

(unweighted) irradiance = $\int \text{spectral irradiance} * d\lambda$ (T1)
(photopic) illuminance = $K_{cd} * \int \text{spectral irradiance} * V(\lambda) * d\lambda$ (T2)
(unweighted) photon irradiance = $\int \text{spectral photon irradiance} * d\lambda$ (T3)

Values for	irradiance, $\mu\text{W.cm}^{-2}$	illuminance, lx	log photon irradiance/[s-1.cm-2]
Enter a title for your data	21.55	0.10	13.953
daylight (D65)	48.82	0.10	14.143

α -opic irradiance, $\mu\text{W.cm}^{-2}$ (T4)
 α -opic irradiance = $\int \text{spectral irradiance} * \alpha$ -opic action spectrum * $d\lambda$

α -opic irradiance for	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
Enter a title for your data	5.06	12.87	16.25	10.13	8.39
daylight (D65)	8.17	14.56	16.29	14.50	13.26

α -opic efficacy of luminous radiation, lm/W (T5)
 α -opic ELR = α -opic irradiance / illuminance

α -opic ELR for	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
Enter a title for your data	0.5057	1.2870	1.6253	1.0126	0.8387
daylight (D65)	0.8173	1.4558	1.6289	1.4487	1.3262

α -opic daylight (D65) efficacy ratio, 1 (T6)
 α -opic DER = α -opic ELR / α -opic ELR for daylight (D65)

α -opic DER for	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
Enter a title for your data	0.6188	0.8840	0.9978	0.6985	0.6324
daylight (D65)	1.0000	1.0000	1.0000	1.0000	1.0000

α -opic equivalent daylight (D65) illuminance, lx (T7)
 α -opic EDI

Values for	irradiance, $\mu\text{W.cm}^{-2}$	illuminance, lx	log photon irradiance/[s-1.cm-2]
User defined spectrum 001	402.00	729.83	15.069
daylight (D65)	356.32	729.83	15.006

α -opic irradiance, $\mu\text{W.cm}^{-2}$ (T4)
 α -opic irradiance = $\int \text{spectral irradiance} * \alpha$ -opic action spectrum * $d\lambda$

α -opic irradiance for	S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
User defined spectrum 001	55.21	101.94	119.61	97.07	87.68
daylight (D65)	59.65	106.25	118.88	105.80	96.79

The user can choose the output prefixes that determine the units used in the output fields below.

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IT-related issues and features

1. The α -opic Toolbox is deliberately **designed without macros** or range names, meaning that it can be integrated with other spreadsheets (including your own macros if you should wish).
2. So if you have **trouble pasting spectral data** into Inputs (reported on some platforms), try adding a blank sheet for pasting and link the Inputs to the cells containing your data on this new sheet.
3. Excel expects you to enter numerical data using the **regional number format settings** on your system. This applies to how you write numbers with decimals, for example “0,1” vs “0.1”.
4. **Unused cells should be cleared** of all contents, including those in the spectral data (Inputs, cells C24:C424). The error messages in red text should alert you to when this has not been completed.
5. The **SI prefix dropdown boxes** temporarily interpret “m” as “M”. However, provided you choose the option you want, this has no further impact, and the calculations will always match the case of the prefix as shown on the Inputs sheet (and Advanced Output sheet) after entry.
6. The **Chart titles’** units are linked to cells H10:H11 of the Advanced Outputs sheet; the y-axis and the **Chart y-axes’** units are linked to cells C12:C13 of the Inputs sheet.
7. Always subject your calculations to **sense-checking** and manual **spot-checking**, based on the data and definitions in CIE S 026:2018. **Please avoid re-using a user-modified Toolbox** (see 1.-2. above).

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